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PYROTECHNICS:
THE HISTORY AND ART
OF FIREWORK MAKING
BY A. ST. H. BROCK, A.R.I.B.A.
WITH NUMEROUS COLOURED
AND OTHER ILLUSTRATIONS

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Brander Matthews

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DEC 8 1959

Dedicated
to the memory of
my brother
Wing-Commander
Frank Arthur Brock, R.N.A.S.
Killed at Zeebrugge
April 23rd, 1918

. be bright and busy
While hoaxed astronomers look up and stare
From tall observatories, dumb and dizzy,
To see a Squib in Cassiopeia's Chair !
A Serpent wriggling into Charles's Wain !
A Roman Candle lighting the Great Bear !
A Rocket tangled in Diana's train,
And Crackers stuck in Berenice's Hair !

Ode to Madame Hengler, Firework-maker to Vauxhall
By THOMAS HOOD.

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INTRODUCTION

THE word "fireworks" as a metaphor, used either to describe the higher flights of oratory, of literature, or of human strife, whether it be in Parliament or the Parish Hall, or merely descriptive of domestic discord, is familiar, even threadbare,

Moreover, the metaphor has generally a humorous flavour; why is this? Is there anything inherently comic about fireworks? It is true that for a short season the less critical of the comic papers used the cracker and squib as pegs upon which to hang the type of joke which depends for its success on the atavistic human trait of laughing at the misfortune or discomfort of others, but this is the lowest type of humour which soon palls upon the mind.

The Stage also has its comedy and clown, yet the mention of the stage is not a signal for mirth. Can any who have heard the long-drawn Ah-h! of rapture from many thousand throats, at the bursting of a flight of shell, or the darting up of the wonderfully tinted rays of the "Magical Illumination" at the Crystal Palace, maintain that the most dramatic moment on the stage is more affecting to the spectators?

Pyrotechny is possibly the only art which can compete with nature; anyone who has seen a first-class firework display will admit that for impressive grandeur, colour effects, and contrasts of light and shade, pyrotechny is unapproached.

Pyrotechny paints on the canvas of the sky; and the results are at once the joy and despair of the artist. Many artists have tried to record their impressions, but the results have been generally disappointing. Whistler came near success, but even his wonderful work conveys merely the dying embers of passed

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glory. One feels that here has been a magnificent display, but the scene in its full grandeur is not depicted.

One of the few black-and-white artists who can approach the subject with some success is Mr. C. M. Padday, an example of whose work is reproduced in the following pages. His success comes from a careful study of the subject, both technically and from the point of view of composition.

That fireworks are popular there is no doubt; no form of amusement is capable of giving enjoyment to so many people at one time; there is no entertainment which so appeals to youth and age of all classes and tastes. And yet it is doubtful if there is an industry concerning which the public at large is so profoundly ignorant.

To the average onlooker any firework which rises in the air is a rocket, any that revolve are catherine wheels; both of these assumptions are incorrect.

What is the average conception of a firework factory? A building, let us say, in which workmen, with sleeves rolled up, are busily engaged in shovelling heaps of gunpowder. How many know that a firework factory consists of dozens of small buildings, the construction of which is exactly defined by law, separated by spaces also specified by law; that workmen may not roll up their sleeves in the danger buildings; or that the amount of gunpowder in each building is strictly limited to a small quantity? All of these restrictions being enforced with the view, of course, of limiting the effects of any explosion that may occur.

So far as I am aware, no history of the art has yet been written. It is true that during the nineteenth century many text-books on pyrotechny were written, but the historical side of the subject has been generally represented by a few disjointed remarks in the prefaces.

INTRODUCTION

My object has not been to write a text-book on firework-making, but rather to trace the art from earliest times, and to give a description of the development and process of manufacture. For those interested in the subject, and desiring fuller information, the list of MSS. and books given in the Bibliography at the end of this volume may be found useful.

My excuse for adding another volume to the literature of the art is that I am of the eighth generation of a family of pyrotechnists, whose work, I venture to claim, has not been without its effect. If I succeed in interesting, and in some degree enlightening, my readers, I shall feel I have not written in vain ; if I fail, I shall know it is not in my choice of subject but in my capacity for dealing with it.

A. ST. H. BROCK.

Sutton,

August, 1922.

ERRATA

Page 117 line 13 for “filled” *read* “fitted”

„ 133 „ 8 „ “and” „ “at”

„ 153 } for “Hume” *read* “Hime”
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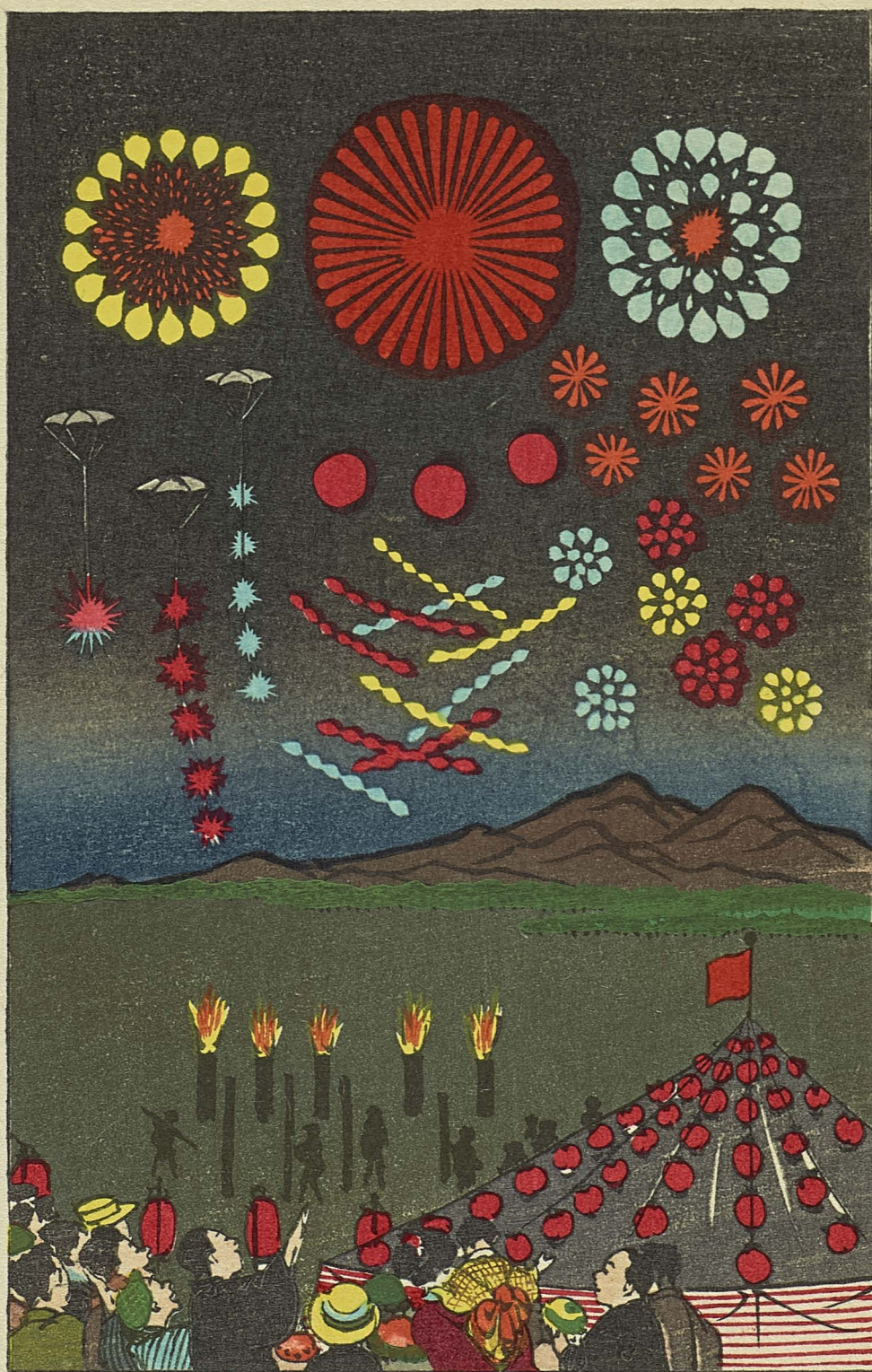
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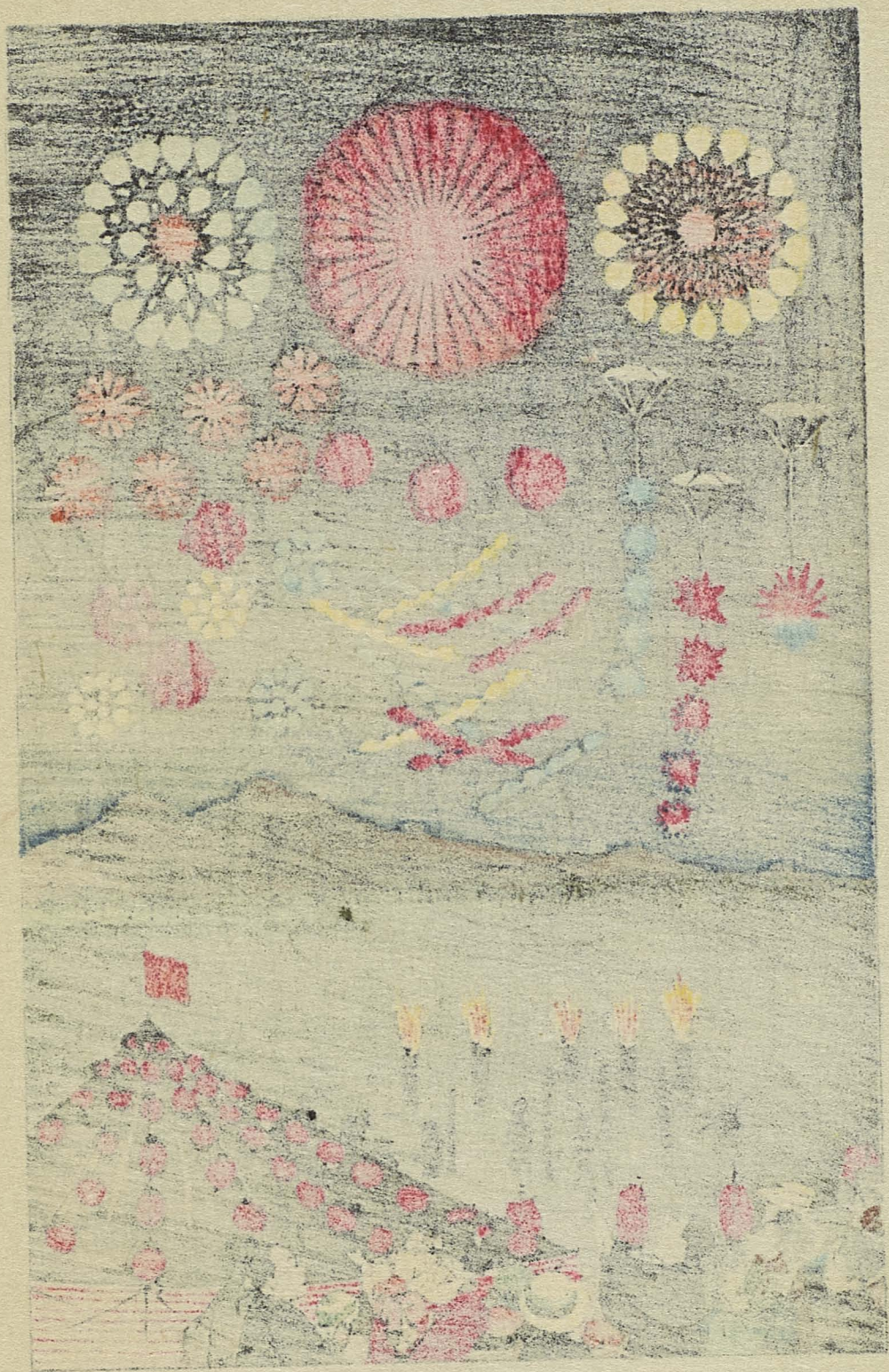
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PART I



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CHAPTER I

THE ORIGIN OF PYROTECHNY

PYROTECHNY, or the Art of Firework-making, is of great antiquity, and the date of its origin is quite unknown; indeed, it would be impossible to define with any degree of exactitude what actually constitutes a firework.

It is curious how universal is the belief that fireworks were dependent upon the invention or discovery of gunpowder. Very little consideration will prove the fallacy of this view; in fact, will show that the reverse is probably the case. In India and China saltpetre (or nitrate of potash) is found in large quantities, and was, no doubt, used by the primitive inhabitants in far-off times for such purposes as curing meat, cooking, etc. The dropping of a quantity in the camp fire may have attracted the attention of some early inventor to the extent of starting him on a series of what were probably the earliest chemical experiments.

He would notice that the presence of saltpetre made the fire burn brighter, and its use as a tinder maker would suggest itself by mixing it with some substance which he knew to be combustible. The most common fuel he knew of was wood, but it must be a powder to mix evenly with saltpetre. Wood is not easily reduced to powder; saws had not been invented, so that he could not add sawdust, and the nearest thing he could get would be charcoal from the fire, which could easily be reduced to powder. With this mixture he would be well on the way to success in elementary pyrotechny.

The next step in his career as the first pyrotechnist is to utilise his composition as an easy means of making fire.

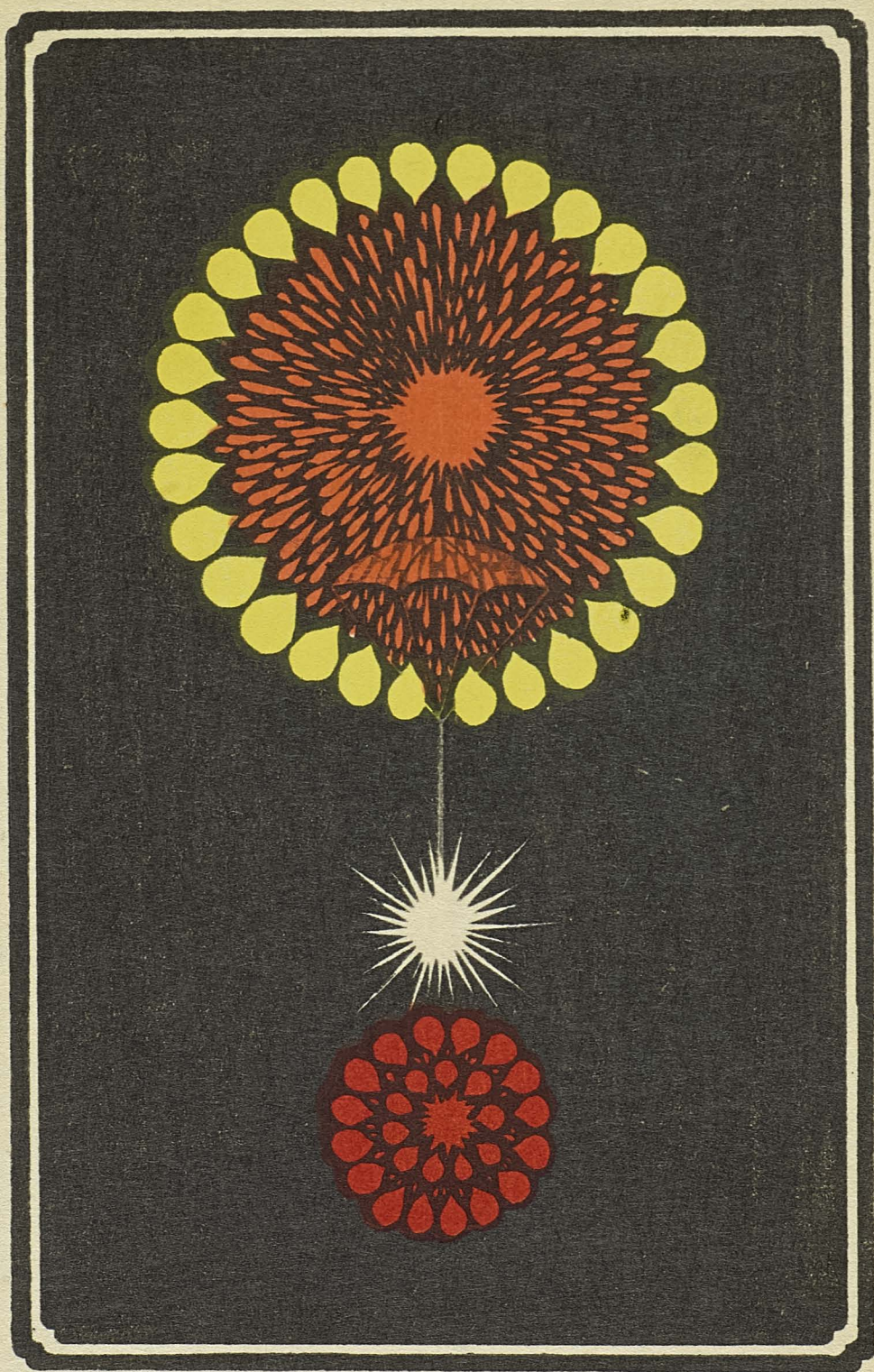
PYROTECHNICS

Gradually he gives up his hitherto necessary tasks of hunting and trapping, as he receives the fruits of other labours in return for his services as fire-maker to the tribe.

The most important item in early social life is fire, the implements for producing it the most valued property of the tribe ; it was the focus of religion and the centre of daily existence, so that any new phenomenon connected with fire would be of the greatest interest to primitive people, and any short cut to the production of fire would be accorded more perseverance and care in its perfection than almost any other invention.

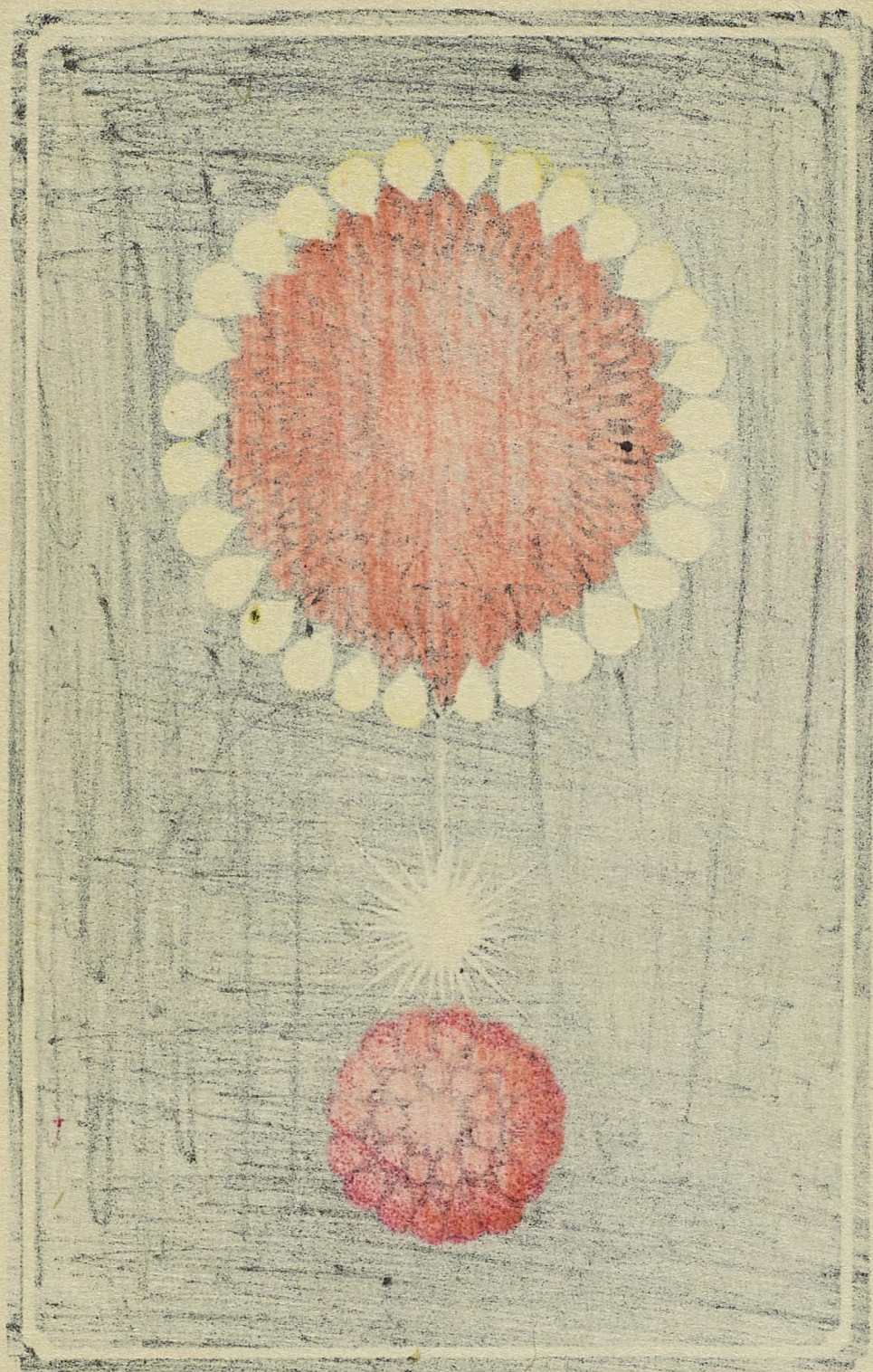
Fire would be struck with a piece of iron pyrites on a flint, small pieces of reguline particles of iron would be detached and fall on the fire mixture unlit. Afterwards, when combustion of the mass of fire mixture took place, these small pieces of metal would scintillate as do the iron filings in a modern firework composition. This would give rise to a further series of experiments, and gradually the composition known as Chinese Fire would be evolved, which is known to have been in use in the East from remote times.

Having arrived at a pyrotechnic composition, attempt to use it in other ways besides fire-making would naturally follow, and sooner or later the idea of filling the mixture into tubes would suggest itself, especially as both in India and China (in one of which countries pyrotechny undoubtedly originated) a serviceable tube—or to use the modern term “ case ”—was ready to hand in any size or quantity in the ubiquitous bamboo. The bamboo is in use for the purpose at the present day in the East, and until recent times, when displaced by European weapons, was used in the construction of ordnance of considerable size. Mortars used for throwing firework shell up to six or more inches in diameter are still in use in Japan and China, the barrel consisting of a section of



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THE ORIGIN OF PYROTECHNY

bamboo strengthened on the outside with a binding of split cane.

Having reached the point of charging composition into a tube, that is to say confining it, a more or less violent explosion was likely or rather certain to follow during the course of the experiments, which might suggest the use of a tube as a means of discharging a projectile. This would lead to research in the direction of the best composition for the purpose and the evolution of gunpowder.

It must be remembered that the constituents of gunpowder must be present in approximately exact proportion, whereas with primitive pyrotechnic compositions, if the ingredients saltpetre and charcoal are present, it is almost impossible to fail in getting some result.

The above suggestion must not be taken literally as a statement of fact, but rather as an attempt on the part of the writer to trace the stages by which pyrotechnic and explosive compositions came to be evolved.

If one disabuses one's mind of the curiously widespread belief that all fireworks are composed chiefly of gunpowder, and that without the invention of gunpower fireworks could not have been constructed, it seems far more likely that pyrotechny is based on the discovery of the assistance given to combustion by saltpetre, than on the discovery of gunpowder.

CHAPTER II

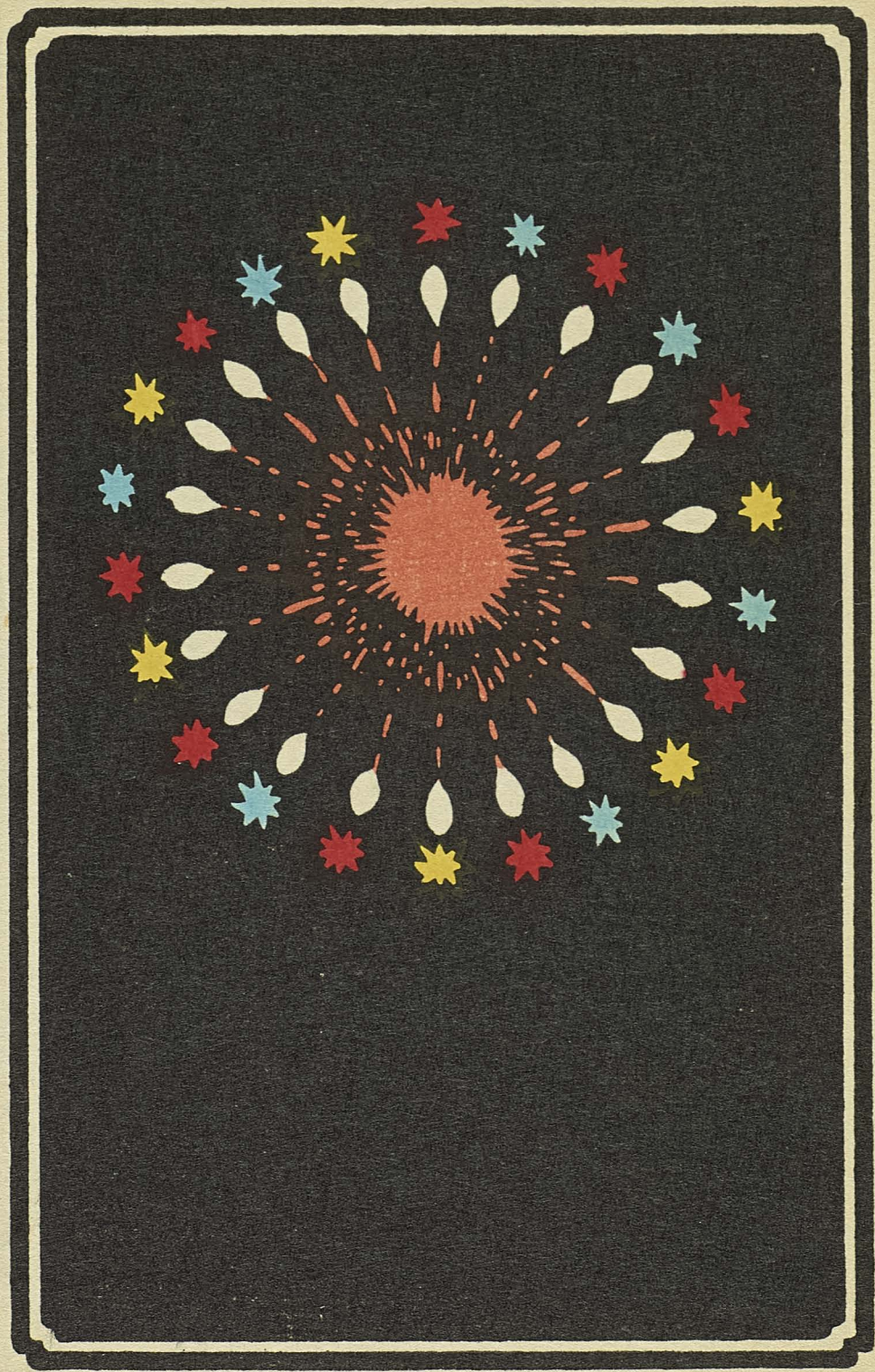
PYROTECHNY IN THE EAST

PYROTECHNY undoubtedly had its genesis in the East, and for that reason we will deal with its development there first. As he has intended to convey, the writer is strongly of opinion that the discovery of pyrotechnic compositions ante-dated that of gunpowder. In many cases earlier writers have discovered passages which they consider prove the use of firearms and gunpowder ; in reality these refer to Greek-fire and similar compositions, which were used as projectiles, being thrown from machines or catapults, and not as propellants. Gunpowder as a mixture of ingredients may have been known from remote times, as undoubtedly were other simple pyrotechnic compositions, but all evidence goes to show that its use as a propellant was not known until well into the Christian Era.

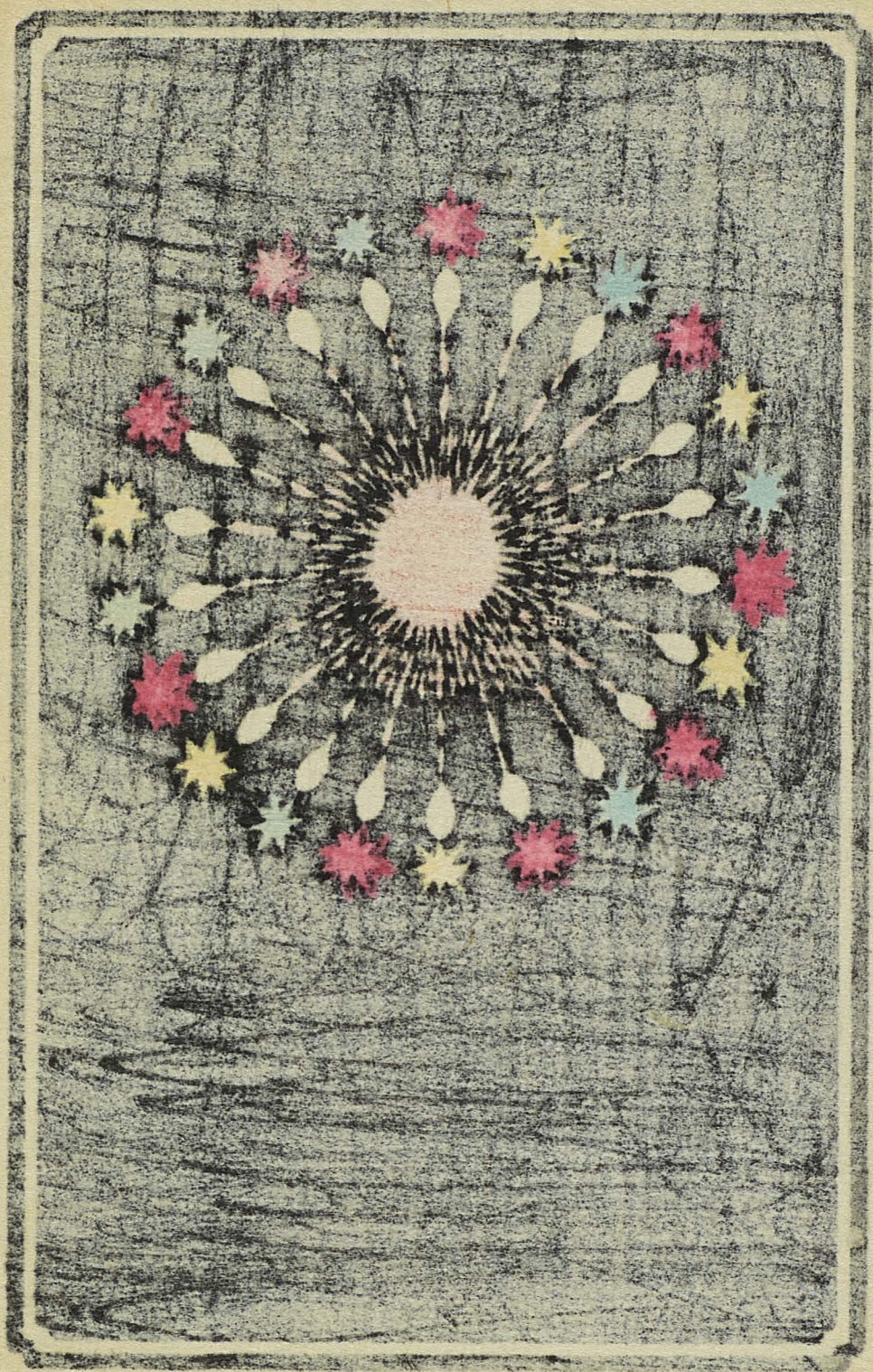
The composition Greek-fire, known in ancient times as " naphtha," was a mixture of pitch, resin, and sulphur, with the addition in some cases of crude saltpetre. It may be considered that in the absence of the latter ingredient the mixture does not constitute a pyrotechnic composition, but from the description of the use of " naphtha " in early writings, it appears at least likely that it was generally present.

The fire was either enclosed in hollow stones or iron vessels, and thrown from a catapult, or sometimes filled into the end of arrows and assisted to propel them forward or sustain their flight.

Philostratus (170-250 A.D.), writing of the Indian Campaign of Alexander the Great (B.C. 326), relates that the inhabitants of a town on the river Hyphasis (Beas) " defended



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PYROTECHNY IN THE EAST

themselves by means of lightning and thunder, which darted upon their besiegers." This has been considered as evidence of the use of firearms, but is more probably the first reference to Greek-fire. Greek-fire or "naphtha" was used at the defence of Constantinople between 660 and 667.

At the siege of Pian-King Lo-Yang (1232), as mentioned in the Chinese Annals, iron pots were thrown containing a burning substance which could spread fire over half an acre, and described by the historians as the "thunder which shakes heaven."

The Mongolians attacking Bagdad in the year 1258 made use of similar vessels, also fire arrows. Marco Polo, describing sieges of towns in China 1268 to 1273, mentions the throwing of fire.

In most of the early records although noise is remarked upon, it is apparently while the projectile is in the air or upon impact; this disposes of the impression which many writers have formed that firearms are referred to, there being no reference to an initial explosion.

Sir George Stanton, writing in 1798 of his embassy to the Emperor of China, says that "nitre (saltpetre) is the daily produce of China and India, and there accordingly the knowledge of gunpowder seems coeval with that of the most distant historic events. Among the Chinese it has been applied at all times to useful purposes . . . and to amusement in making a vast variety of fireworks—but its force had not been directed through strong metallic tubes, as it was by Europeans soon after they had discovered that composition."

Although the place of origin of the art, pyrotechny has not developed in the East as rapidly as in Europe, except in Japan.

Japanese pyrotechnists, with that wonderful capacity for careful and exact manual work which is so characteristic of the race, have developed aerial fireworks, that is to say, the

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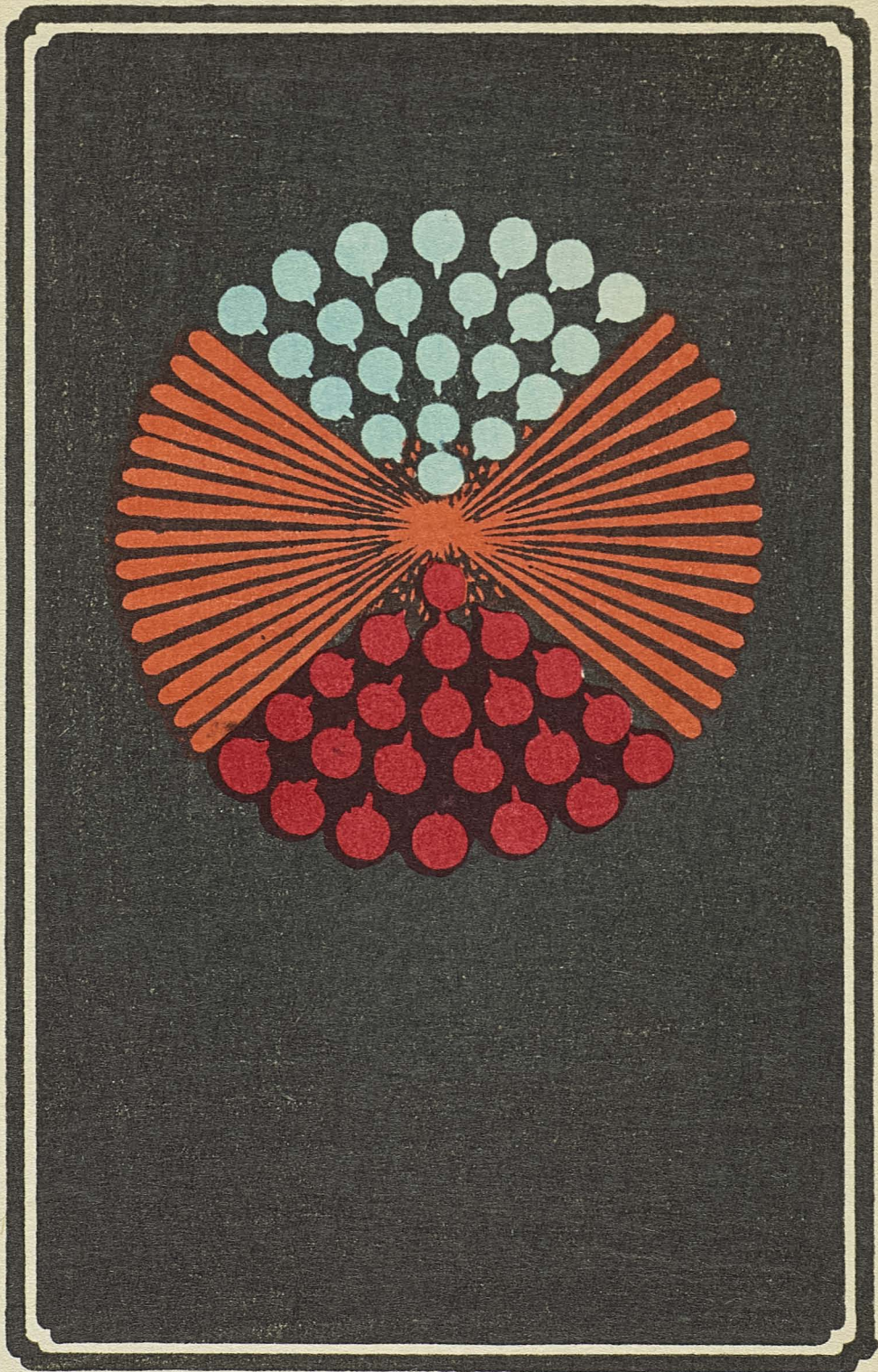
shell, to a remarkable degree of perfection. The compositions used are not to be compared with European manufactures in point of colour or brilliance, but the effects obtained are extraordinary. The stars, upon the bursting of the shell, are thrown out in symmetrical patterns and designs, several examples of which are given in the accompanying Japanese colour prints.

Daylight fireworks also originated in Japan. Instead of pyrotechnic effects, the shell contains a grotesque balloon in the form of an animal, human figure, or other form, which, being open and weighted at the lower end, becomes inflated as it falls and remains in the air for a considerable period. Other daylight effects are coloured clouds formed by coloured powder, distributed by the bursting of the shell, showers of streamers, confetti, and toys.

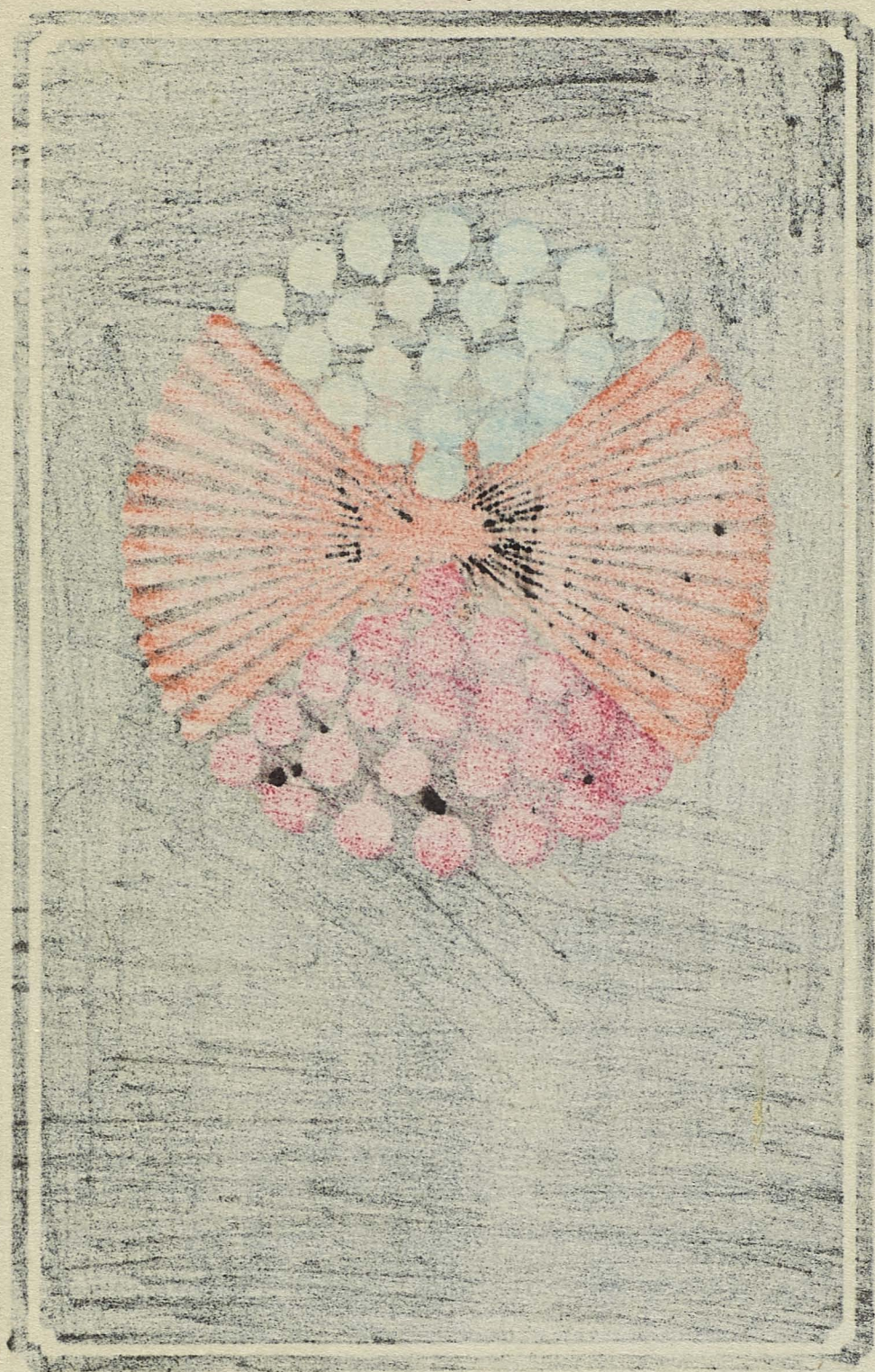
Chinese firework displays have often been enthusiastically described by travellers in China. Whether it is that the glamour of the East distorts the perceptions, or that these travellers have not seen a European firework display, there is no doubt that such descriptions are, to say the least, over coloured.

Chinese fire (a composition of saltpetre, iron filings, sulphur and charcoal), a few simple colour compositions, and a large number of Chinese crackers of varying sizes constitute a Chinese display ; the rest of the exhibition being eked out with lanterns, pictures, etc., which certainly do not come under the heading of pyrotechnics.

The writer once had an opportunity of witnessing a Chinese display of some importance, lasting several hours, which produced the effect on the mind of watching some performance or game of the rules of which one was in entire ignorance. Pyrotechnically, only the crudest effects were produced, the remainder of the display, consisting of such items as a man slowly climbing a ladder carrying a lantern, was to the uninitiated mystifying.



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The following is an account by a traveller in the early nineteenth century of a Chinese display : “ The fireworks, in some particulars,” says he, “ exceeded anything of the kind I had ever seen. In grandeur, magnificence, and variety they were, I own, inferior to the Chinese fireworks we had seen at Batavia, but infinitely superior in point of novelty, neatness and ingenuity of contrivance. One piece of machinery I greatly admired : a green chest, five feet square, was hoisted up by a pulley fifty or sixty feet from the ground, the bottom of which was so contrived as then suddenly to fall out, and make way for twenty or thirty strings of lanterns, enclosed in a box, to descend from it, unfolding themselves from one another by degrees, so as at last to form a collection of full five hundred, each having a light of a beautifully coloured flame burning brightly within it. This devolution and development of lanterns was several times repeated, and at every time exhibiting a difference of colour and figure. On each side was a correspondence of smaller boxes, which opened in like manner as the other, and let down an immense network of fire, with divisions and compartments of various forms and dimensions, round and square, hexagons, octagons, etc., which shone like the brightest burnished copper, and flashed like prismatic lightnings, with every impulse of the wind. The whole concluded with a volcano, or general explosion and discharge of suns and stars, squibs, crackers, rockets and grenades, which involved the gardens for an hour in a cloud of intolerable smoke. The diversity of colour, with which the Chinese have the secret of clothing their fire, seems one of the chief merits of their pyrotechny.”

It will be seen that lanterns play an important part in the exhibition, and that when the fireworks proper are reached, the result is an “ intolerable smoke.”

Indian pyrotechnists are more advanced than their Chinese

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neighbours. Firework displays carried out by them are nowadays more or less crude attempts to reproduce European work.

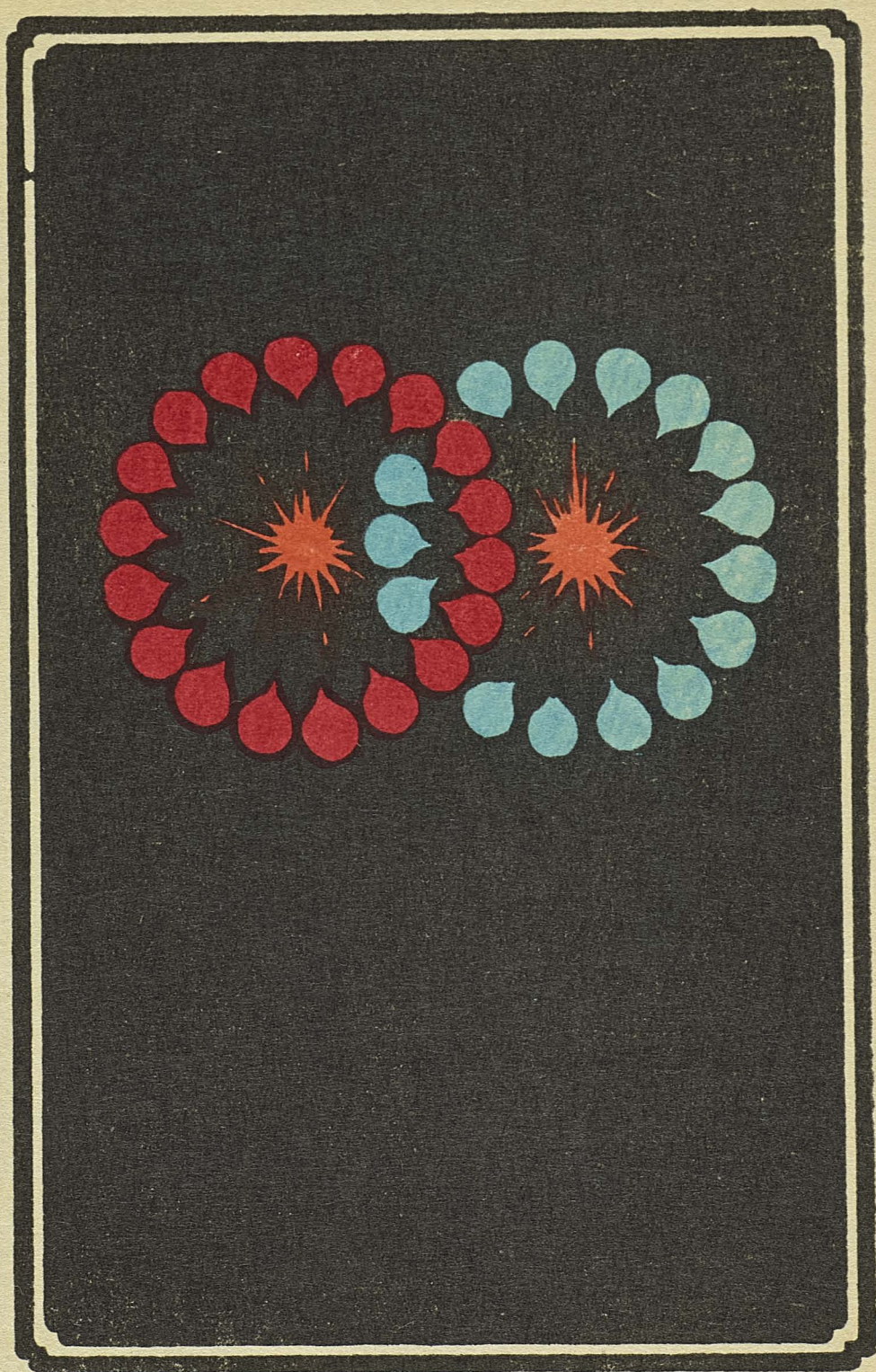
The writer has seen a set piece evidently intended to follow a fire picture seen in a European display carried out by small wicks burning in oil instead of the "lances," as the small fireworks used to outline the pictures are called in this country.

In India as in China fireworks play a frequent part in religious and civil ceremonies. In the former country, at certain festivals, a primitive device for producing a series of reports is used. These are called "adirvedis," and consist of a series of short iron tubes fitted to a wooden plank, charged with gunpowder and tamped with clay.

At weddings, crackers are largely used under a variety of names, such as Vengagvedi, Gola, Pataka or Koroo. To-day these are simple crackers filled with country-made gunpowder or the imported Chinese crackers. Formerly almost the only composition used was chlorate of potash and one of the sulphides of arsenic. A favourite form consisted of a small quantity of the two ingredients put together unmixed into a piece of rag with some small stones or grit and tied. The resulting fireworks were similar to the "throw-down" crackers sold in this country.

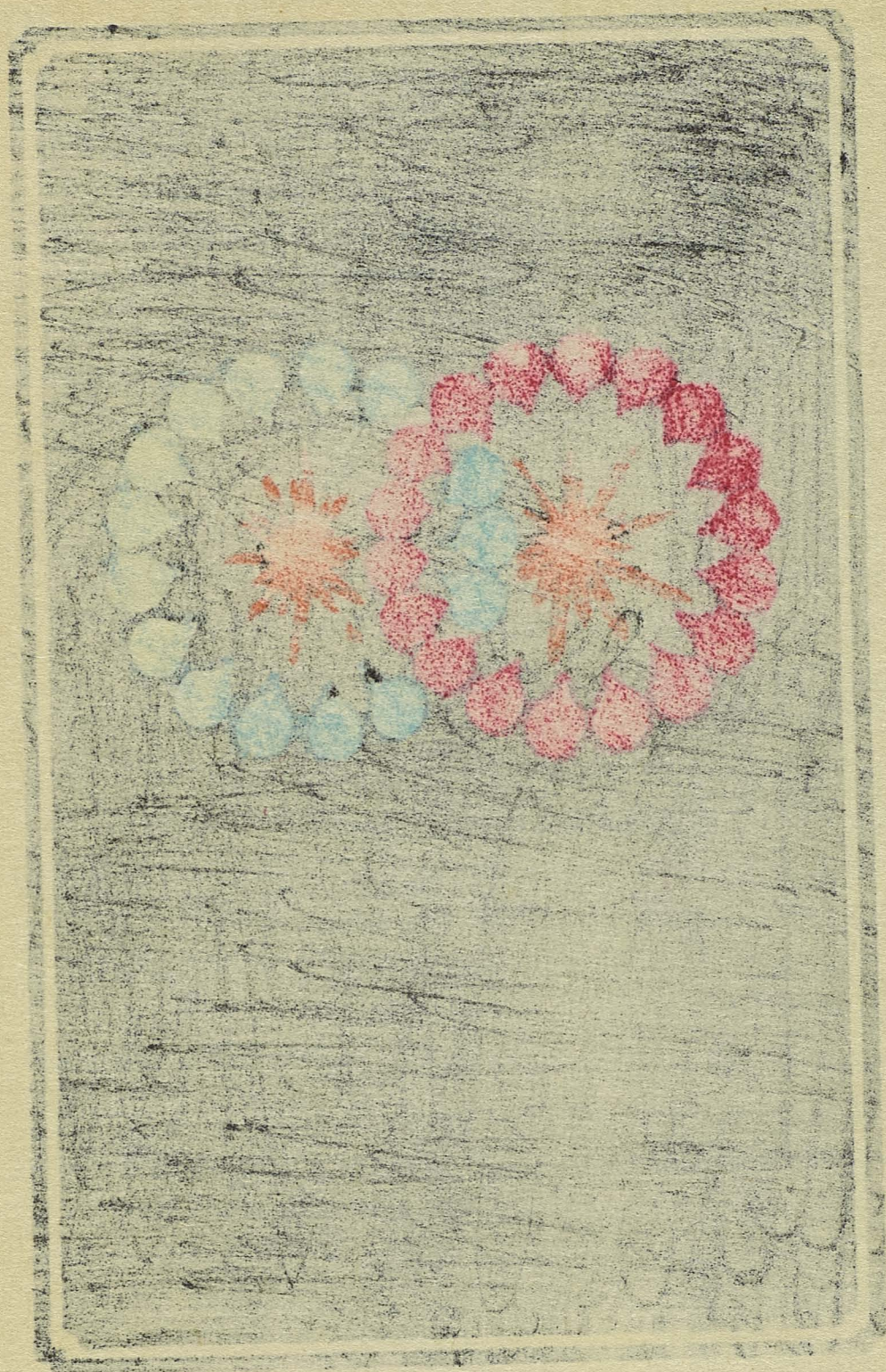
Owing to the very large number of accidents caused by the casual methods, both in manufacture and use, with this highly sensitive composition, H.M. Chief Inspector of Explosives for India endeavoured, in 1902, to secure its prohibition, as was done in this country in 1895, but it was not until 1910, when it had been established that this composition was being used by anarchists, that it was finally prohibited.

The most successful effect produced by Hindoo pyrotechnists is the "Tubri." The composition is here known as



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PYROTECHNY IN THE EAST

Chinese fire, a mixture of charcoal, saltpetre, sulphur and iron dust, charged into either bamboo tubes or earthen pots.

It is a common practice to fix a pot at either end of a long bamboo, which is whirled quickly about by a performer ; the result produced is quite good, but seems rather to come under the heading of juggling than that of pyrotechnics proper. As the pots are theoretically the wrong shape for such a purpose, that is to say, a large mass of composition is burning through a narrow orifice, premature explosions are frequent. This want of theoretical knowledge is noticeable throughout, but such incidents seem to be appreciated as part of the show.

Another use of the earth pot is the "burusu," a kind of red flare ; the composition used being sulphur, saltpetre, and nitrate of strontia. Flare compositions are also used loose as in England, and are known as "chandrajota" or "mahteb."

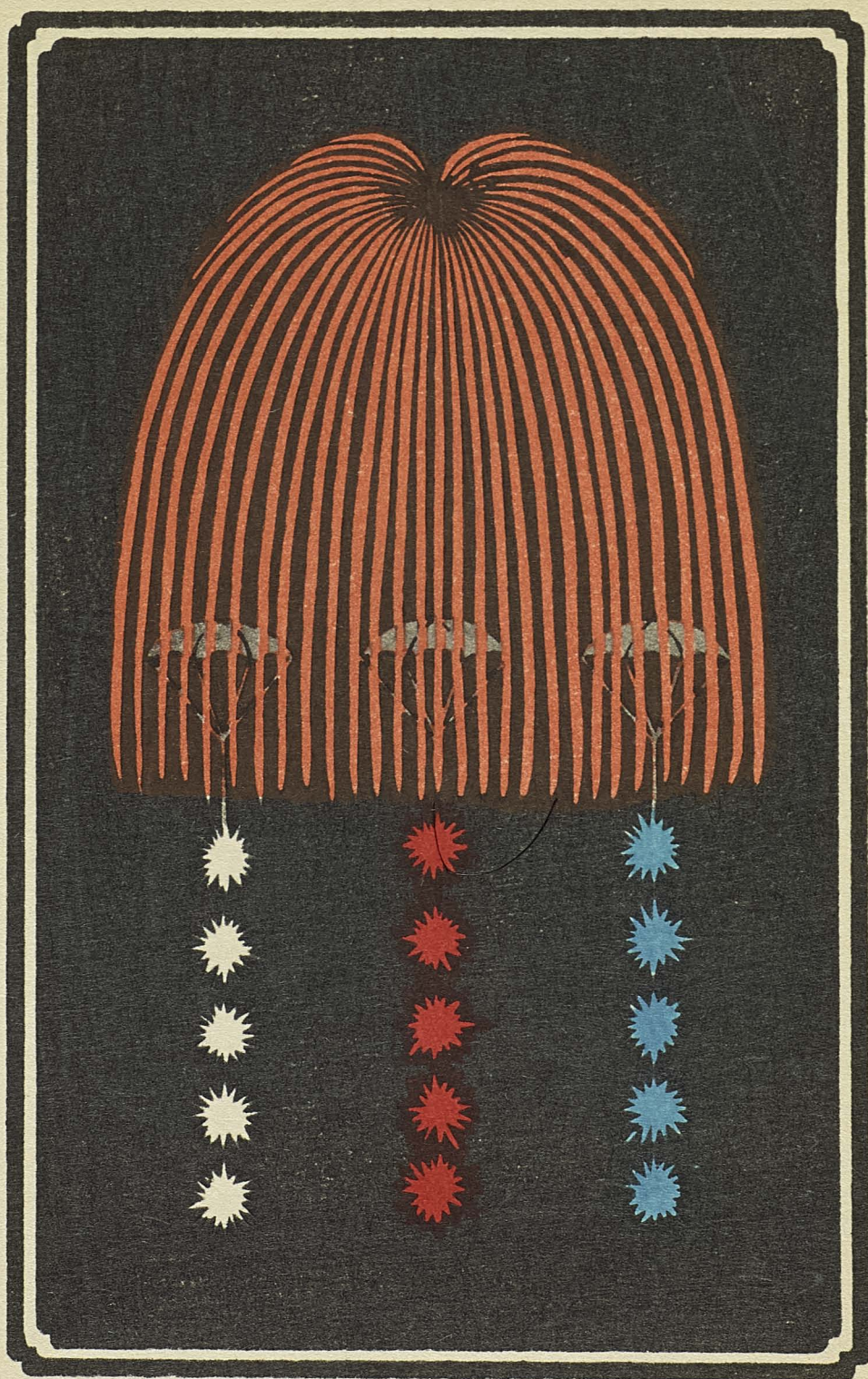
Abusavanani or Hawai, that is to say, rockets, are now made similarly to those manufactured in Europe except a bamboo case is most generally used, but formerly chlorate of potash and orpiment seem to have been employed for this purpose.

The firework shell under the name "out" is also manufactured very much as in this country, except that the range of effects is very limited, simple coloured stars being almost the only "garniture" used.

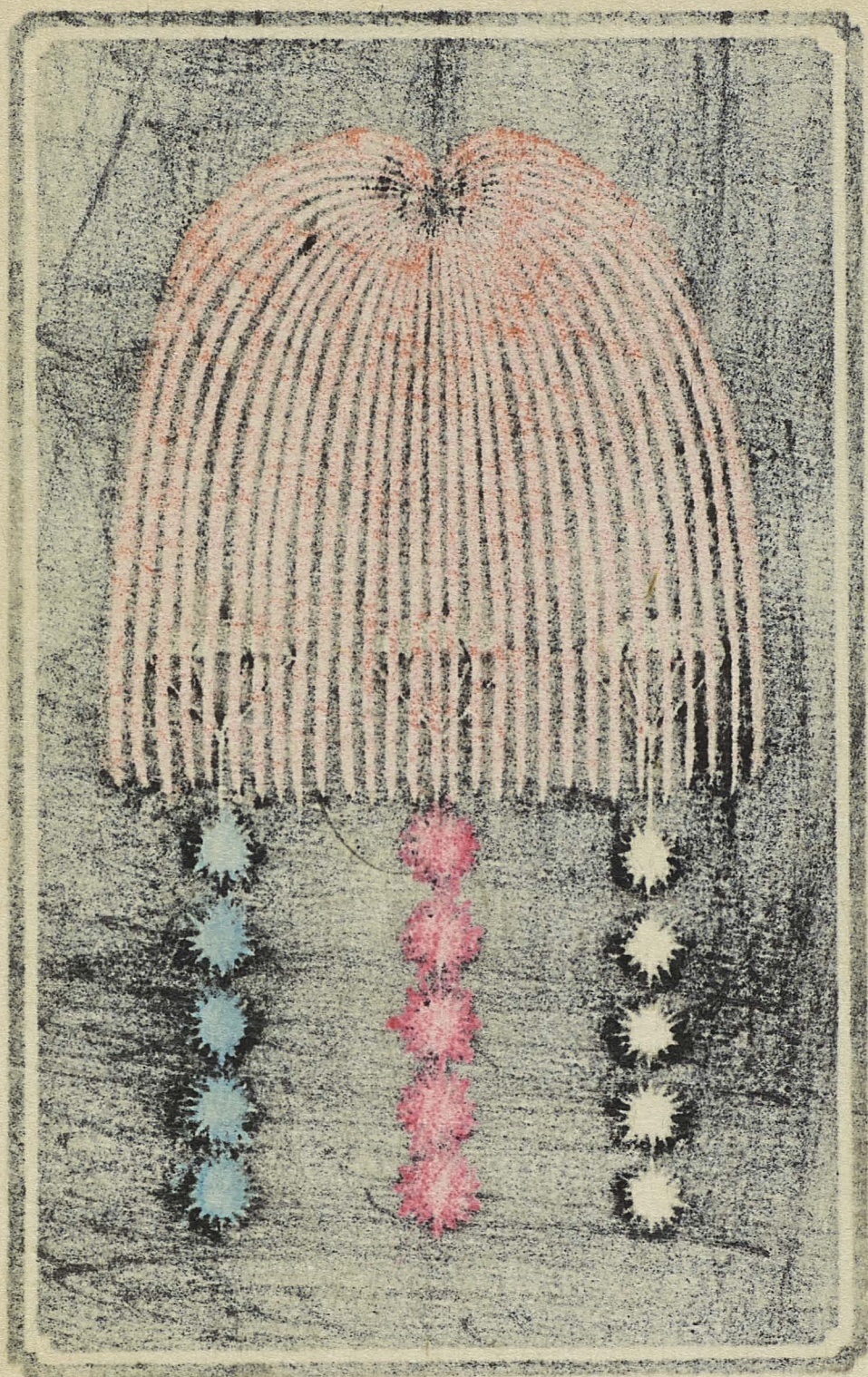
In Siam it is a custom, and one apparently of considerable antiquity, to celebrate certain religious festivals with firework displays. These displays take place in the day-time, and take the form of discharges of rockets, some of which are of very large size ; a writer giving their length, exclusive of the stick, as from 8 ft. to 10 ft. The case is composed of a section of bamboo bound with string. The composition consists of coarse native powder, of which from 20 lbs. to 30 lbs. is often used in one case. The rocket stick, which is of bamboo, varying

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from 20 ft. to 40 ft. in length, is gaily decorated with coloured paper and tinsel and fitted with bamboo whistles. A rough scaffold is erected from which to fire the rockets, and according to those who have witnessed such exhibitions, considerable altitudes are reached by the rockets in flight. As may be expected with such crude methods, mishaps are of frequent occurrence.



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CHAPTER III

PYROTECHNY IN EUROPE

PYROTECHNIC compositions and gunpowder are inextricably mixed together in early European records; for our inquiries it will serve no useful purpose to disentangle them, the latter being only a particular case of the former. We will therefore deal with them together, taking the evidence of the knowledge of one as that of both, as until gunpowder is specifically mentioned as being used as a propellant in a gun or similar weapon, there is nothing to distinguish it from any other pyrotechnic composition.

The earliest record of European pyrotechny is in Claudius' account of the public festivities during the consulate of Theodosius in the fourth century A.D., in which he describes fire "which ran about in different directions over the planks without burning or even charring them, and which formed by their twisting and turning globes of fire."

Leo VI, Emperor of the East, in a work written about A.D. 900, says: "We have divers ways of destroying the enemies' ships, as by means of fire prepared in tubes, from which they issue with a sound of thunder, and with a fiery smoke that burns the vessels on which they are hurled. A tube of tin must be put on the front of the ship to hurl this from."

The most interesting reference of an early date is supposed to have been written by Marcus Graecus in his "*Liber ignium ad comburendos hostes*" (Book of fires for burning up the enemy), in which he not only gives the exact proportions of the compositions, but describes what is virtually the modern cracker, and also a primitive form of rocket. The

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case of the former was only partially filled, as with the jumping cracker of to-day, and although the wording is not very explicit, it was apparently bent in a similar way.

The date of this work is a subject of controversy ; some writers place it as early as the eighth century, and it can only be said with certainty that it is not later than 1280. The latter date is fixed by the death of Albertus Magnus, who, in his book "*De mirabilibus mundi*," from internal evidence, is obviously plagiarising the *Liber Ignium*.

Friar Roger Bacon (1214-94), in two of his works, refers at least twice to compositions containing saltpetre, powdered charcoal, and sulphur. In one place he refers to fires that "shall burn at what distance we please" ; in another to "thunder and corruscations," which references seem to suggest that he is describing something of a pyrotechnic nature rather than the simple effect of gunpowder. His description in no way indicates that he claimed to be the inventor, but rather as something well known before.

Dr. Jebb, in his preface to Bacon's "*Opus Majus*," refers to what seems to be an early example of both the rocket and the cracker.

Dutens, in his "*Inquiries into the Origin of the discoveries attributed to the Moderns*" (1790), makes reference to many early writers, which are mostly so vague and exaggerated that no definite conclusion can be drawn from them ; most refer to the early uses of Greek-fire or similar composition.

Don Pedro, Bishop of Leon, says that "in 1343, in a sea combat between the King of Tunis and the Moorish King of Seville . . . those of Tunis had certain iron tubes or barrels wherewith they threw thunderbolts of fire."

This description, if accurate, may be thought to suggest the use of cannons, but it is more likely to refer to the use of

PYROTECHNY IN EUROPE

Greek-fire ; this composition will, in certain proportions, if charged into a strong tube, give intermittent bursts, projecting blazing masses of the mixture to a considerable distance. The writer has seen this effect produced in a steel mortar of $5\frac{1}{2}$ inches diameter, the masses of composition being thrown a distance of upwards of a hundred yards, a considerable range in the days of close warfare. Anyone who has seen this phenomenon will at once realise that here probably is the true solution of many obscure early references to explain which so much ingenuity has been expended.

An interesting fact which seems to have escaped the notice of writers on this subject is that Theresa, daughter of Alfonso V. King of Leon and the Asturias (A.D. 999), when married to Abdallah, King of Toledo, took for device on her coat of arms a mortar in which a powder is being pounded. This powder is supposed to represent gunpowder, a supposition which is supported by the motto, "*Minima maxima fecit*" (A little makes much). If gunpowder is intended, this must be one of the earliest references to its quality of exploding, and it is difficult to explain the meaning otherwise.

Richard Cœur de Lion used Greek-fire on his galley at the siege of Acre in 1191, and it is thought by many that it was introduced into Western Europe by the Crusaders, who had learned its use in the East.

Alfonso Duke of Ferrara had as his coat of arms a bomb-shell in flight, and Antoine de Lalaing, Count of Hoogstraeten, had a bomb-shell exploding in water. The adoption of these two devices at about the same time (1540) seems to indicate that this projectile was coming into use, that is to say, for military purposes at least.

An early reference to shell appears in Stowe's *Chronicles* (1565). He mentions two foreigners, Peter Brand and Peter Van Cullen, a gunsmith, in the employ of Henry VIII (A.D.

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1546), who "caused to be made certain mortar pieces being at the mouth eleven inches unto nineteen inches wide, for the use whereof to be made certain hollow shot of cast-iron, to be stuffed with firework or wild-fire, whereof the bigger sort for the same had screws of iron to receive a match to carry fire kindled, that the firework might be set on fire for to break in pieces the same hollow shot, whereof the smallest piece hitting any man would kill or spoil him." The missile is to all intents the firework shell of the present day, except that the modern shell has a papier-maché case.

The reference to "firework" without further explanation seems to indicate that by this time the word was well established in use. Shakespeare makes three references to fireworks. In "Love's Labour's Lost," Act V, Scene 1, Don Armado says: "The King would have me present the Princess with some delightful entertainment, or show, or pageant, or antic, or firework." In "Henry VIII," Act I, Scene 3, we read of "fights and fireworks"; and again in "King John," Act II, Scene 1: "What cracker is this same that deafs our ears?"

However, nothing in the nature of a firework display appears to have taken place, at least in this country, before the time of Elizabeth.

The use of fire for theatrical purposes, as in Mystery Plays to represent the "gate of Hell," has been taken by some to refer to fireworks, but this seems doubtful as flames are mentioned, and it is more probable that a torch or similar contrivance was used.

When, however, we read a description of a barge at the coronation of Anne Boleyn, in 1538, carrying a dragon "casting forth wild fire—and men casting fire," the reference to some pyrotechnic effect, however primitive, seems fairly obvious.

THE SECOND BOOKE

Teaching most plainly, and withall
most exactly, the composing of all
manner of Fire-works for Tryumph.
and Recreation.

By I^OH^N BATE.



LONDON,
Printed by Thomas Harper for Ralph Mab.
1635.

Facsimile Title-page of Bate's Book, showing a "Green Man."

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The men performers may be considered as early types of the "green man" who made his appearance somewhat later. The office of this performer was to head processions carrying "fire clubs" and scattering "fireworks" (probably sparks) to clear the way.

One account of a procession to the Chester Races on St. George's Day, 1610, commences as follows: "Two men in green ivy, set with work upon their other habit, with black hair and black beards, very ugly to behold, and garlands upon their heads, with great clubs in their hands, with fireworks to scatter abroad to maintain the way for the rest of the show."

The fire clubs referred to are described in John Bate's book, published in 1635; the same writer illustrates a "green man" on the title page of his work.

Regarding the origin of the Green Man, it has been suggested that the character was evolved from the wild men, satyrs, monsters, etc., which appeared in the earlier exhibitions. This may or may not be so, but another explanation suggested to the writer by an old Danish print of the sixteenth century is at least plausible.

This print, which apparently represents a floating firework device of the old scenic type, shows two figures carrying fire clubs wearing leaves, and suggesting immediately the green man of a slightly later date.

Behind them are two figures holding rockets, leaving no doubt that a firework display is portrayed.

On the other hand, apart from the fact that normally they have no fire issuing from their clubs, the supporters of the Danish royal arms might be here depicted; a supposition which is borne out by the fact that the figure surmounting the erection carries the crown and sceptre of Denmark.

It seems quite within the bounds of possibility that these two figures were introduced into Danish displays as a compliment

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to Royalty, and that later they appeared in England, and became, as it were, acclimatised. Colour is lent to this belief by the record of a display given on a float by the King of Denmark in 1606 upon his departure from this country, where he had been on a visit to his brother-in-law, James I.

This exhibition seems to have given James a taste for fireworks, and one at least of the Danish artists appears to have remained in this country, as some months after James had a display carried out by "a Dane, two Dutchmen, and Sir Thomas Challoner."

In 1572 a firework display was given in the Temple Fields, Warwick, by the Earl of Warwick, then Master-General of the Ordnance. The occasion was a visit to the castle by Queen Elizabeth, who appears to have been rather partial to such exhibitions.

The display consisted of a mimic battle, with two canvas forts for a setting; noise was provided by the discharge of ordnance of various sizes; the fireworks proper seem to have taken the form of flights of rockets. The display was evidently conducted in a somewhat reckless manner, some houses being set on fire, and some completely destroyed, the two inhabitants of which are said in a contemporary report to have been in bed and asleep, although how that could be with continuous discharge from twenty pieces of ordnance, to say nothing of "qualivers and harquebuses," in the immediate neighbourhood, is to say the least curious.

Two other displays attended by Elizabeth were those at Kenilworth in 1572 and at Elvetham in 1591.

The first European people to make headway in the art of pyrotechny proper appear to have been the Italians. Vanochio, an Italian, in a work on artillery, dated 1572, attributes to the Florentines and Viennese the honour of being the first who made fireworks on erections of wood, decorated with statues



Petrus Faber Lugdunensis, sculp.

A Display of the Earliest Type. From a contemporary print (c. 1650).

PYROTECHNY IN EUROPE

and pictures raised to a great height, some in Florence being forty ells, or seventy-two feet high. He adds that these were illuminated so that they might be seen from a distance, and that the statues threw out fire from the mouths and eyes.

He refers to the practice, which survived up to the end of the eighteenth century, of constructing elaborate temples or palaces richly decorated, with transparencies illuminated from inside, statuary, gilding, floral and other decorations. On these erections the fireworks proper were displayed, and which were then called artificial fireworks. Nothing very large in the way of firework set-pieces seems to have been attempted, but effect was gained by repetition of a small device over the facade of the building.

Displays were given annually in Florence at the Feast of St. John and the Assumption. This custom extended to Rome, where the festivals were given on the Feast of St. Peter and St. Paul, and at the rejoicings on the election of a Pope.

The towers and fortifications of the castle of St. Angelo furnished suitable spots for these, being visible from the greater part of the city of Rome, and what are described as braziers, firepots, and other fires would be placed there, so as to give a great display without the expense of a building.

Evelyn, the famous diarist, gives an account of one such display which he witnessed in 1664.

In other towns that wished to imitate the festival of Rome, it was arranged to place illuminations on the highest towers and steeples of the towns, but as it was found that there was considerable danger of fire from these, it was afterwards preferred to make suitable erections in the great public squares, which were convenient for the exhibition itself, and also for the sightseers.

The Italians appear to have held the supremacy until the end of the seventeenth century.

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In the book of Artillery by Diego Ufano, written in 1610, we read that only very simple fireworks were made in his time in Spain and Flanders, consisting of wooden framework supporting pots of fire wrapped round with cloth dipped in pitch, but that more than fifty years before magnificent spectacles could be seen in Italy.

In 1615, on the occasion of the marriage of Louis XIII, a display was given at Paris in the Place Royale, in which were included combats between men carrying illuminated arms.

In 1606 the Duc de Sully gave a spectacle which depicted a battle between savages and monsters, the former throwing darts and fire. A similar display had previously been given on the occasion of the entry of Henry II into Rheims, and it was repeated in 1612.

These spectacles, which are quoted as firework displays, cannot rightly be considered as such, fireworks playing a comparatively secondary part in the exhibitions.

A display of this nature to celebrate the capture of Rochelle was conducted by Clariner of Nuremberg, a celebrated pyrotechnist of the day.

During the reign of Louis XIV, 1638-1715, great advances were made in pyrotechny in France; great displays were given on the return of the King and Queen to Paris in 1660, on five consecutive days at Versailles in 1676, also on the occasion of the birth of the Dauphin in 1682, in Paris at the Louvre, Dijon, and Lyons.

A particularly fine display in celebration of the Peace of Riswick, 1669 (for which event displays took place in several countries), is mentioned by Frezier, who wrote a treatise on pyrotechny (1747); it was, he says, witnessing this display that inspired him to study the art.

One of the chief causes of progress in France was the



REPRESENTATION DU FEU D'ARTIFICE

*Eleve' devant l'Hotel de Ville par l'Ordre de M^{rs} les Prevost des Marchands et Echevins de la Ville de Paris, en jouissance de la prise de la Ville et Chateau de GAND le 11. et 15. Juillet 1745. par l'Armée du ROY, commande' par sa Majesté.
Ce Feu a été exécuté le 2. Aoust 1745. sous la conduite de M^r Beausire Architecte du Roy et de son Academie d'Architecture.
M^r General Con^{te} Inspecteur des Batimens de la Ville.)
Inventé et peint par les S^{rs} Dumesnil frères Peintres ord^{rs} de la Ville, et l'Artifice exécuté par le S^r Dodement Artificier ordi^{naire} de la Ville)*

Paris chez de Poilly et chez Herissot Graveurs rue S. Jacques avec Pr. du Roy.

Set Piece of the Scenic Type.

PYROTECHNY IN EUROPE

encouragement given by Louis XV (1710-1774) to the pyrotechnists Morel Torr  and the Ruggieri brothers, the latter being Italians from Bologna who became naturalised Frenchmen, and contributed very greatly to the development of French pyrotechny. They were the first to rely chiefly on fireworks for the effect, instead of using them merely to embellish a scenic or architectural structure.

Louis XV expended large sums of money on displays, one of the finest being that fired at Versailles in 1739 by Ruggieri, on the occasion of the marriage of Madame La Premi re of France with Don Philippe of Spain. Writing of this display in 1821, Ruggieri's son says : " There appeared for the first time the Salamander la Rosace and le Guilloche, which are still admired to-day." These are purely pyrotechnic pieces and devices ; similar or identical ones are used at the present day, which seems to indicate that fireworks proper were making headway against scenic effect.

Other displays in France during the eighteenth century were those on the occasions of the birth of the Duke of Brittany, 1704 ; birth of the Dauphin, 1730 ; the convalescence of the King, 1744 ; and the return of the King to Paris, 1745. Also there is in existence a series of prints which, but for the fact that they are described as fireworks, would be taken to be scenic tableaux ; whether the figures are human beings or wax-works is not indicated. These were erected in celebration of the following events :—The taking of Tournay, the taking of Chateau Grand, Victory over the Allies, all dated 1745 ; the taking of Ypres, 1747, all of which took place in Paris before the Hotel de Ville. Similar displays were given in Lyons in 1765 to celebrate the taking of Fort San Philippe, and at Soleure in 1777, in honour of the Swiss Guard.

Displays took place at Versailles (1751) on the occasion of the birth of the Duke of Burgundy. In 1758-9 came a further

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series of victory celebrations in honour of the victory of Lutzelberg, over the English in America, and over the Allies at Bergheri, all of which appear to have been of the " tableau " type mentioned above.

There were also displays for the peace celebrations on the Seine, 1763, the birth of the Dauphin, 1782, in the Place de Geneve, and peace rejoicings, 1783, before the Hotel de Ville.

Ruggieri, however, states in his book that the display fired on the marriage of Louis XVI (or, as he then was, the Dauphin) was the only display since the great fetes of 1739 which showed any considerable advance in the art ; he may, however, be in some degree biased as his father was concerned in each of these displays.



Abriß des Kayßerlichen Feuerwercks Schloßes: vnd BARRAQUEN/
worinnen das Fried vnd freudenmahl gehalten wurde vor Nurnberg auff d. Joh. Schützplatz. A. 1650.

Firework Display at Nuremberg, 1650. From a contemporary engraving

CHAPTER IV

PYROTECHNY IN EUROPE (*continued*)

DURING the later part of the seventeenth century, and subsequently, many prints appeared depicting firework displays; their number seems quite out of proportion to the total number of prints published in that period.

Possibly this may be taken as some indication of the popularity of firework displays at the time, or may give the measure of the favour in which they were held by the artists of the day.

Many of these prints are of little value to the student of pyrotechny, as they merely depict the more or less elaborate structure for the display by daylight, and whatever may be their architectural or artistic merit there is generally no indication of what actual fireworks were to be used, or how they were to be displayed.

In some cases a list of the works is given under the engraving, adding greatly to its value in the eyes of the pyrotechnist, and some, although they are considerably in the minority, are intended to represent the display in progress, although on the rather futuristic method of showing everything going off at one time.

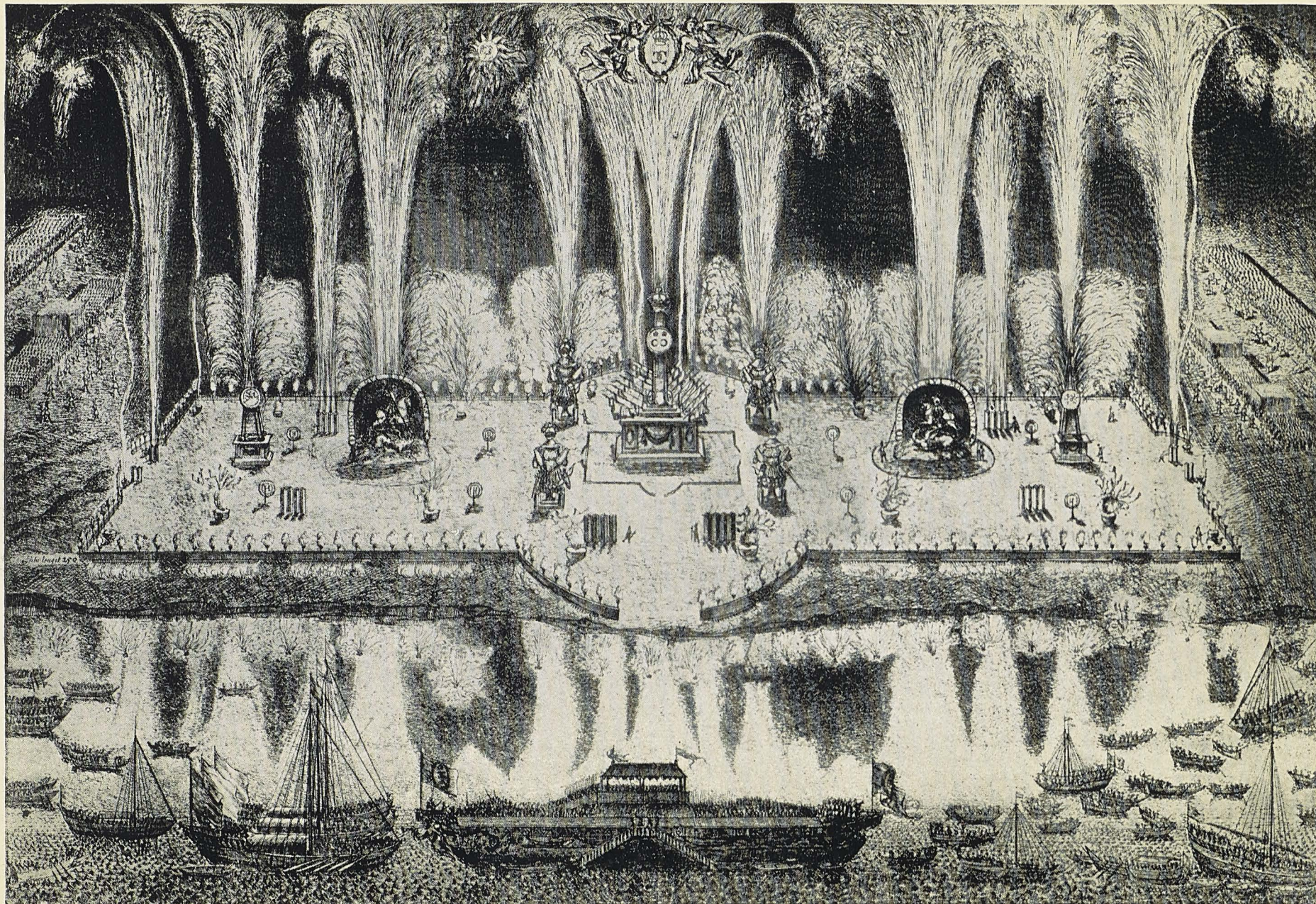
A series of prints published in Germany during the seventeenth century are among the earliest in which a serious attempt is made to depict pyrotechnic effects; the series includes "Swedish Fireworks," dated 1650; "Fireworks at Nuremburg in celebration of Peace," of the same date; "Fireworks given at Pleissenburg by the Prince of Saxony," 1666; and the same year, "Fireworks at Vienna"; all three

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prints show a good display of rockets, also bonfires, and there are indications of primitive wheels. The same remarks apply to a very fine plate published in 1669, depicting a display given at Stockholm in honour of the investiture of Charles XI of Sweden with the Order of the Garter by the British Ambassador. This engraving carries with it a feeling of conviction that it is an actual representation of the scene, and not—as is the case with earlier and with some later work—that the artist is drawing on his imagination. In many of the earlier prints it is difficult to judge if the artist is depicting what he imagined, or monsters and scenic effects actually constructed for the display.

It is worthy of note that even in early times, speaking pyrotechnically, the value of water in enhancing the effect of fireworks seems to have been realised. The display at Stockholm we have already mentioned appears to have taken place on the sea front. Many of the larger French displays of the seventeenth and eighteenth centuries were fired with a foreground of water; in those at Versailles full advantage was taken of the wonderful fountains and ornamental water, the display given in celebration of the entry of Louis XIV in Paris after his marriage being given on the Seine, and many of the early English displays took place on the Thames. Probably the earliest contemporary account of any length of a firework display in England is one headed “The Manner of Fire-Workes shewed up upon the Thames” in celebration of the marriage of Prince Frederick (Elector Palatine) with the daughter of James I in 1613. We read “many artificiall concusions in Fire-Workes were upon the Thames performed.

“First, for a welcome to the beholders a peale of Ordnance like unto a terrible thunder ratled in the ayre. . . . Secondly, followed a number more of the same fashion, spreading



Great Firework Display near Stockholm, July, 1669. To celebrate the Investiture of Charles XI, King of Sweden, with the Order of the Garter by King Charles II.

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so strangely with sparkling blazes, that the skie seemed to be filled with fire. After this, in a most curious manner, an artificiall fire-worke with great wonder was seen flying in the ayre, like unto a fiery Dragon, against which another fierrie vision appeared flaming like to Saint George on Horse-backe, brought in by a burning Inchanter, between which was then fought a most strange battell continuing a quarter of an howre or more ; the dragon being vanquished, seemed to roar like thunder, and withall burst in pieces, and so vanished ; but the champion, with his flaming horse, for a little time made a shew of a tryumphant conquest, and so ceased.

“ After this was heard another ratling sound of Cannons, almost covering the ayre with fire and smoke, and forthwith appeared, out of a hill of earth made upon the water, a very strange fire, flaming upright like unto a blazing starre. After which flew forth a number of rockets so high in the ayre, that we could not chose but approve by all reasons that Arte hath exceeded Nature, so artificially were they performed. And still as the Chambers and Culverines plaide upon the earth, the fire-workes danced in the ayre, to the great delight of his Highnes and the Princes.

“ Out of the same mount or hill of earth flew another strange piece of artificiall fire-worke, which was in the likeness of a hunted Harte, running upon the water so swiftly, as it had been chaced by many huntsmen.

“ After the same, issued out of the mount a number of hunting-hounds made of fire burning, pursuing the aforesaid Harte up and downe the waters, making many rebounds and turnes with much strangenes ; skipping in the ayre as it had been a usual hunting upon land.

“ These were the noble delights of Princes, and prompt were the wits of men to contrive such princely pleasures.

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Where Kings commands be, Art is stretcht to the true depth ; as the performance of these Engineers have been approved.

“ But now again to our wished sports : when this fiery hunting was extinguished, and that the Elements were a little cleared from fire and smoke, there came sailing up, as it were upon the Seas, certaine ships and gallies bravely rigged with top and top gallant, with their flagges and streamers waving like Men of Warr, which represented a Christian name opposed against the Turkes ; where, after they had awhile hovered, preparing as it were, to make an incursion into the Turkish country, they were discovered by her Towers or Castles of defence, strongly furnished to intercept all such invading purposes, so sending forth the reports of a cannon, they were bravely answered with the like from the gallies, banding fire and powder one from another, as if the God of Battle had been there present.

“ Here was the manner of a sea-fight rightly performed : First, by assailing one another, all striving for victorie, and pursuing each other with fire and sword : the Culverines merrily plaid betwixt them, and made the ayre resound with thundering echoes ; and at last to represent the joyes of a victorie, the Castles were sacked, burned, and ruined, and the defenders of the same forced to escape with great danger.”

The foregoing appears to be the only full account of a display in England during the early part of the seventeenth century, but in the first serious work on fireworks, “Pyrotechnia,” by John Babington, “gunner and student of the mathematicks,” we find a proposed programme for “a generall piece of fire-worke for land, for the pleasure of a Prince or some great person.” The spectacle consists of two castles with mechanical effects, but includes such devices as horizontal and vertical wheels, flights of rockets, line rockets and “torches of beautifull fire.” Babington also describes the

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St. George and Dragon device, which is merely scenic, the figures being of wickerwork and canvas with slight firework effects. At this time, according to a "History of Colleges in and arround London," there were "many men very skilful in the art of pyrotechny and fireworks."

In a book on fireworks, published in the same year, by John Bate, the author concludes by saying: "I might have been infinite in the describing of such like with Ships, Towers, Castles, Pyramides. But, considering that it would but increase the price of the book and not better your understanding, since all consist of the former workes, which are so plainly described as that the most ignorant may easily conceive thereof, and (if any whit ingenious) thence contrive others, of what fashion they list." From this it would appear that firework displays were by that date a well-established institution.

Pepys, in his account of the coronation of Charles II, 1661, says: "We staid upon the leads and below till it was late, expecting to see the fireworks, but they were not performed to-night." He seems to have looked upon fireworks as a matter of course on such an occasion. However, a display of considerable size did take place, conducted by Sir Martin Beckman, later Firemaster to James II, who was responsible for most of the important displays until 1706. One of the earliest prints of an English firework display is that depicting the fireworks on the Thames at Whitehall for the coronation of James II, 1685, in which the artist appears to have drawn somewhat on his imagination.

Three years later an elaborate display was given on the Thames to celebrate the birth of an heir to the throne, who was afterwards known as the Old Pretender. In the same year we again see fireworks on the Thames, this time to celebrate the reception of the Prince of Orange.

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In 1690 displays were given, again on the Thames, and in Covent Garden, on the occasion of the King's return from Ireland.

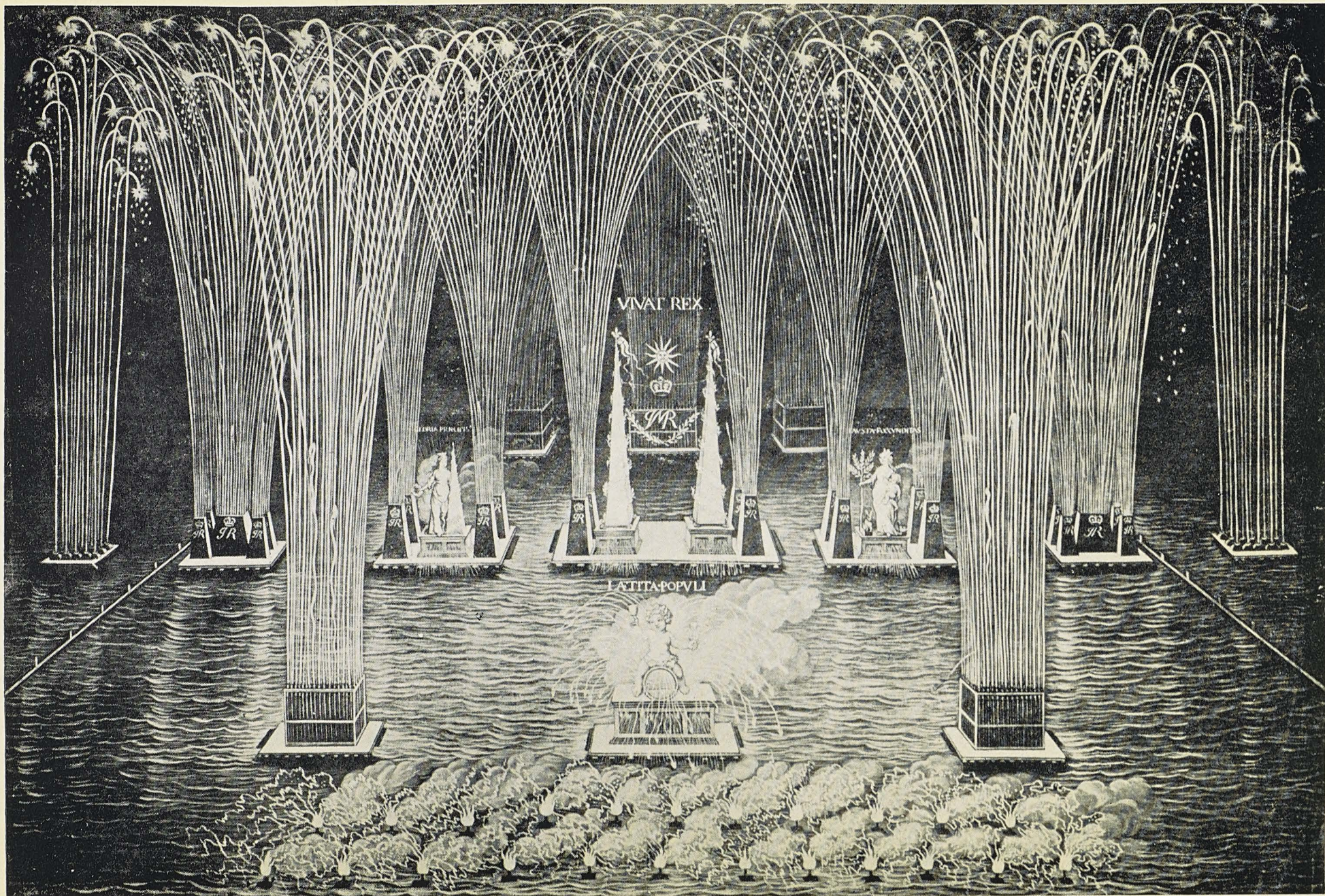
The taking of Namur, 1695, was celebrated by a display in St. James's Square, and on the same site two years later, the celebrations for the Peace of Riswick. This latter is depicted in a fine engraving, giving the following list of fireworks used on the occasion:—"1,000 Sky Rockets, from four to six pounds weight; 200 Shell; 2,400 Pumps with Starrs (Roman Candles); 1,000 Cones; 7,000 Reports; 15,000 Swarms; 400 Light Balls; 23 Rocket Chests, each containing 60 rockets from one to four pounders."

John Evelyn, in his "Diary," says: "The evening concluded with illuminations and fireworks of great expense." The display cost £12,000.

There seem to have been no fireworks in London at the coronation of either Anne or the first two Georges, although on the former occasion rockets appear to have been fired from the Fleet at Spithead.

The Peace Rejoicings of 1713 were the occasion of another display on the Thames off Whitehall, the erection being about 400 feet long on barges chained together in the stream. A feature of this display was the water fireworks, described as: "1,500 small and large water Rockets; 5 large water Pyramids; 4 water fountains; 13 Pumps; 21 standing Rockets, with lights all swimming on the water; 84 of Coll Borgards; large and small Bees swarms, half of which were set with lights to swim on the water."

The next event to be celebrated by firework displays on a large scale was the Peace of Aix-la-Chapelle; these were given at Paris, The Hague, London, and St. Stephen's Green, Dublin. The Duke of Richmond was responsible for a display on the Thames off Whitehall, the official display taking



Fireworks on the Thames, June 17th, 1688. To celebrate the birth of a son to King James II, known to fame first as the Prince of Wales, and afterwards as the Old Pretender.

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place in Green Park, and was on a scale unequalled in this country until well into the last century. It was conducted by the famous pyrotechnist Gaetano Ruggieri, who came over from France for the purpose, assisted by Gioseppe Sarti, under the direction of the Board of Ordnance.

Following the practice of the period, an elaborate structure was prepared. The following is taken from the official programme :

“ A DESCRIPTION OF THE MACHINE FOR THE FIREWORKS, &c.

“ The Machine is 114 feet high to the Top of His Majesty's arms, and is 410 feet long. It was invented and designed by the Chevalier Servandoni and all the framing was performed by Mr. James Morris, Master Carpenter to the Office of Ordnance.

“ The Ornaments of this Machine are all in Relief, and it is adorned with Frets, Gilding, Lustres, Artificial Flowers, Inscriptions, Statues, Allegorical Pictures, etc.”

According to a contemporary newspaper report, the construction occupied from November 7th until April 26th. It was composed of timber covered with canvas, whitewashed and sized.

The display commenced about six o'clock, and continued until after twelve ; during the display the left wing caught fire, which prevented the firing of some of the devices. Indeed, according to Walpole, the Duke of Richmond's display on the Thames a few weeks later consisted largely of fireworks which had not been fired owing to this occurrence, and which the noble duke had bought up cheap.

Among the items were included the following :—Regulated Pieces, Fixed Suns, Stars of six Points, and between each point a Ray, a large vertical Sun moved by double Fires,

PYROTECHNICS

Cascades, Pyramids (40 feet high) of Gerbs, etc., etc. The chief piece seems to be one "from whence Fire issues out and retires within, twelve times alternately; when without, it forms a Glory; when within, it composes a Star of eight Points, and then changes to a Royal brilliant Wheel, whose Fire is thirty feet in diameter, and is moved by twelve fires."

The remainder of this century in England appears to be rather barren of firework displays on a large scale.

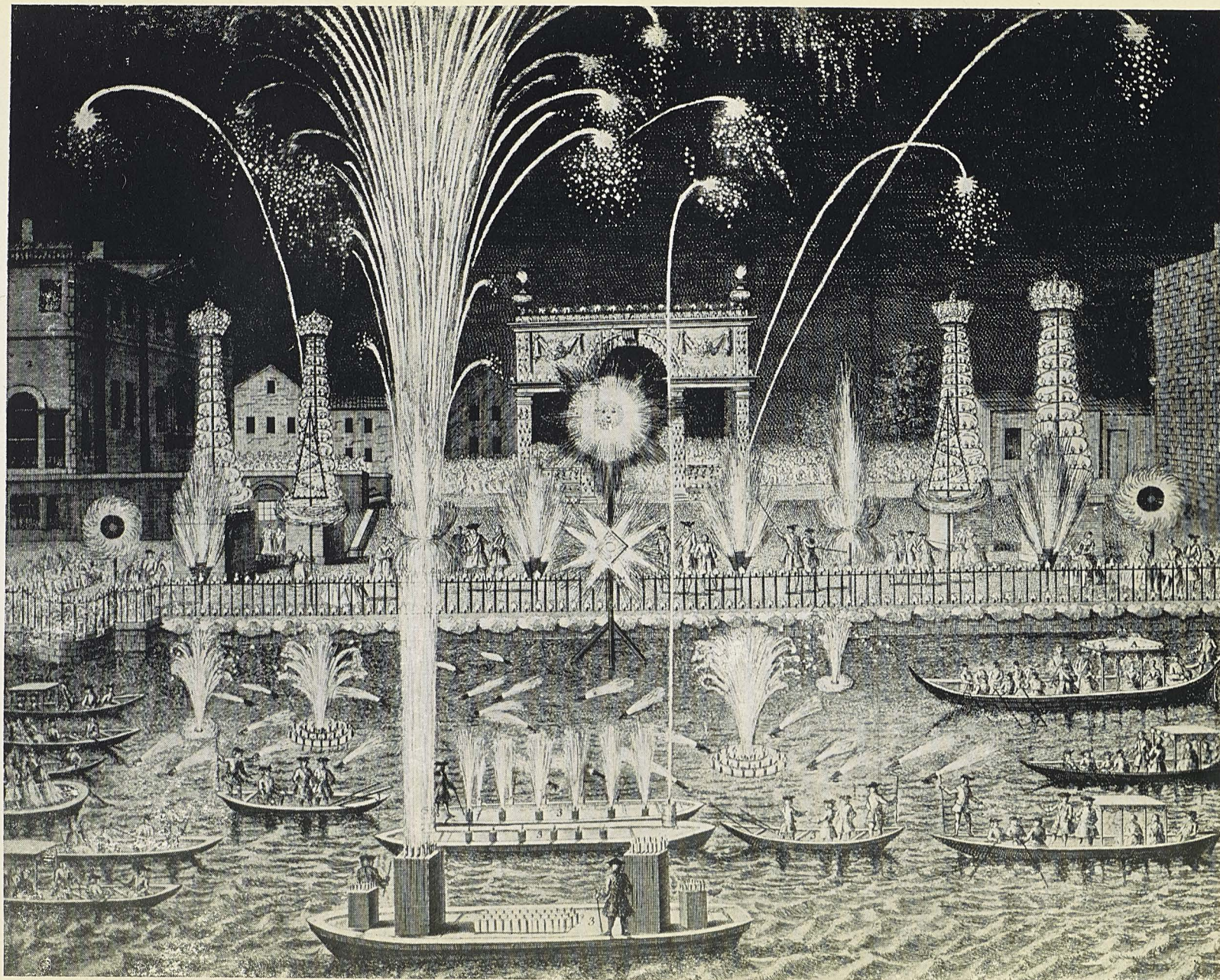
A writer in the "St. James's Chronicle," under the date February 18th, 1764, in a letter advocating certain improvements in St. James's Park, evidently recalling the outcry over the 1749 display, observes: "We had no fireworks at the peace last year, that will surely obviate any argument preferred against the expense of the undertaking."

Until nearly the end of the eighteenth century, according to Strutt, writing at that time, it was customary "for the Train of Artillery to display a grand fire-work on Tower Hill, on the King's Birthday, but owing to the disturbances that occurred, the inhabitants a few years since petitioned against it." There was, however, a great increase in the number of displays. Fireworks became a feature of the programme of the majority of the then fashionable tea and pleasure gardens.

Walpole describes a firework display given in 1763 by the notorious Duchess of Kingston, who was thirteen years later tried by her peers on a charge of bigamy.

The display appears to have taken place in Hyde Park, opposite the residence of the Duchess, then at the height of her popularity. He records that "the fireworks were fine and succeeded well." One item seems curious to modern ideas; it took the form of a cenotaph for the Princess Elizabeth, a sister of the king, bearing the inscription: "All honours the dead can receive."

The sequel was even more extraordinary, as "about one



Firework Display given by the Duke of Richmond on the Thames off Whitehall, May 15th, 1749,
to celebrate the Peace of Aix-la-Chapelle.

PYROTECHNY IN EUROPE

in the morning this Sarcophagus burst into crackers and guns."

Lieutenant Jones, who published a book on fireworks in 1765, in his preface makes the following remarks :

" I own I cannot help reflecting with some kind of chagrin that whenever we have had occasion for these sort of diversions to be exhibited in England we have almost always had recourse to foreigners to execute them ; if this has been owing to the ignorance of our own people on this subject I shall be very happy if it is in my power to correct it ; if it is only owing to that prevailing fondness we entertain for everything foreign I know no remedy for that evil but time and experience."

To a certain extent his complaint seems justified ; as we have seen, the Aix-la-Chapelle celebrations were conducted by foreigners—Ruggieri and Sarti. Later in the century, Morel Torré, who, as previously mentioned, collaborated with Ruggieri in pyrotechnic displays for Louis XV, and several other pyrotechnists came to this country and conducted displays. At the same time, however, there were undoubtedly many capable pyrotechnists of English nationality, who found scope for their abilities in the exhibitions given in the pleasure gardens of London and the provinces in the eighteenth and early nineteenth centuries.

A history of pyrotechny would not be complete without a survey of these popular places of amusement, and we propose in the following chapter to give a brief summary of the better known places of resort.

CHAPTER V

THE LONDON PLEASURE GARDENS

DURING the eighteenth and first half of the nineteenth centuries the Pleasure Gardens filled a position in the lives of a large proportion of the public comparable with that of the Cinema to-day.

To the great mass of the public, the most general form of evening relaxation was a visit to one or other of these places of resort. Apart from meals of a more or less elaborate nature, and liquid refreshments of various kinds, a great variety of entertainments were provided, varying from displays of horsemanship to exhibitions of paintings. Of these diversions none were more general than fireworks and illuminations. At many gardens fireworks formed a regular feature of the programme, at others, generally less ambitious undertakings, displays were confined to occasions, such as the King's Birthday.

Space will hardly permit of more than a glance at those resorts situated in the provinces, but a description of those in the London area may be taken as typical.

Captain Marryat, in "Peter Simple," gives an account of a visit to Postdown Fair, near Portsmouth, and an adjournment to the local Ranelagh Gardens to "see the fireworks." As the pyrotechnist was behind time, Peter Simple and his friends took it upon themselves to fire the display. "In about half a minute off they all went in the most beautiful confusion; there were silver stars and golden stars, blue lights and Catherine Wheels, Mines and Bombs, Grecian fires and Roman Candles, Chinese Trees, rockets and illuminated mottoes, all firing away, cracking, popping, and fizzing at the same time. It was unanimously agreed that it was a great improvement on the intended show."

THE LONDON PLEASURE GARDENS

Undoubtedly the gardens best remembered at the present day are Vauxhall and Ranelagh, neither of which were early in the field in presenting firework displays to the public.

The first displays took place at Vauxhall about 1798, more than half a century after their appearance at some of the less famous gardens, and did not become a permanent feature of the programme until 1813. They continued regularly until the final closing of the gardens in 1859, the final item of the programme being "Farewell for Ever" in letters of fire. In 1813 an item in the firework programme was the performance of Madame Saqui, which was to slide down an inclined rope 350 feet long from the top of a mast 60 feet high, erected on the firework platform, enveloped in fireworks. So popular did this exhibition become that it was repeated here by other performers, by Longueman in 1822, and later by Blackmore.

The best-known pyrotechnists connected with Vauxhall were Southby, Mortram, and Hengler, the first display being by an Italian named Invetto.

Pyrotechnic displays at Ranelagh became a prominent feature of the amusements about 1767. The pyrotechnists Angelo, father and son, during that and the following years, helped to establish these displays in popularity, followed by Clithero, Caillot, Brock, Rossi, and Tessier, up to the closing of the gardens in 1805, after which date they appear to have been opened from time to time on special occasions. "The Morning Chronicle" of June 1st, 1812, announces that "By the Authority of the Right Hon. the Lord Chamberlain" these gardens would be open "in Honour of His Majesty's Birthday, with a grand naval and military Fete, and a superb exhibition of Fireworks."

An interesting old advertisement, dated 1766: "For the Benefit of the General Lying-in Hospital. The most superb

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and Magnificent Fireworks ever exhibited at that Place, under the conduct and direction of Mr. Angelo." It would appear from this that fireworks had been fired at Ranelagh earlier than 1766, but they could not have been a regular feature before 1767.

Cupers Gardens, which stood on the south side of the river, approximately on the site of the Waterloo Bridge approach, were for a long period the scene of popular firework displays. Commencing about 1741, these displays were as elaborate as any of this period. The earlier displays appear to have been conducted by "the ingenious Mr. Worman," who seems to have relied to a considerable extent on transparencies and scenery; in 1749 and 1750 he reproduced in miniature the firework "machine" or Temple used in the respective official displays in Green Park, and at The Hague for the Aix-la-Chapelle peace celebrations. Other scenic effects were a view of the city of Rhodes with a model of the Colossus; Neptune, issuing from a grotto below drawn by sea-horses, set fire to a pyramid or an "Archimedean worm" and returned.

Clithero was also associated with these displays, producing similar scenic effects, including a naval engagement in 1755, which was the last year of fireworks in these gardens.

The earlier displays at Marylebone Gardens took place about the middle of the eighteenth century. In 1751 a display is announced to take place at eleven o'clock, and "a large collection" of fireworks was advertised in 1753. Some at least of these earlier displays were fired by Brock, whose son, later on, worked here in conjunction with Torr . In 1769 the displays were under the direction of Rossi and Clanfield. From 1772 to 1774 was the most successful period of the fireworks at these gardens; they were then under the direction of Torr . A popular item, afterwards copied by Marinari at Ranelagh, was the "Forge of Vulcan," a scenic display concluding with the eruption of Mount Etna.

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On the occasion of Torr 's benefit, in 1772, there was a further exhibition of this kind, representing Hercules delivering Theseus from Hell.

During this period attempts were made by neighbouring residents to stop the displays as a nuisance, but nothing came of it, and the fireworks continued.

At the annual festival in 1772, the display included a temple of "upwards of 10,000 cases of different fires, all lighted at the same time."

Other pyrotechnists firing at the gardens were Clithero and Caillot, both of whom had conducted displays at Ranelagh, the latter being responsible for the fireworks up to the closing of the gardens about 1778.

It is recorded that Dr. Johnson once visited the gardens on a firework night, but unfortunately a wet one, and notice was given to the handful of visitors that the fireworks were wet and the display would be cancelled. The doctor, however, was of opinion that it was a "mere excuse to save their crackers for a more profitable company," and suggested that a threat to break the lamps would result in the show being forthcoming. Some young men standing by endeavoured, under his direction, to ignite the pieces, but unsuccessfully.

The Mulberry Gardens, Clerkenwell, were among the earliest to make fireworks a feature. Displays took place from the opening in 1742, and ten years later Clanfield gave a display each evening.

Two neighbouring taverns, "Lord Cobham's Head" and the "Sir John Oldcastle," had displays from 1744, and in 1751 "New fireworks in the Chinese manner" were announced at the latter establishment.

The New Wells, in the same neighbourhood as the foregoing, had had a display as early as 1740, but it appears to have been of a scenic nature, representing the Siege of Portobello.

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The "Star and Garter," Chelsea, advertised displays by Signor Genovini of Rome, in 1762, and "Jenny's Whim," in the same neighbourhood, had displays somewhat earlier, the place having been established as a pleasure resort by a pyrotechnist.

Cromwell Gardens, in the vicinity of the present Cromwell Road, had what appears to have been a small display in 1784.

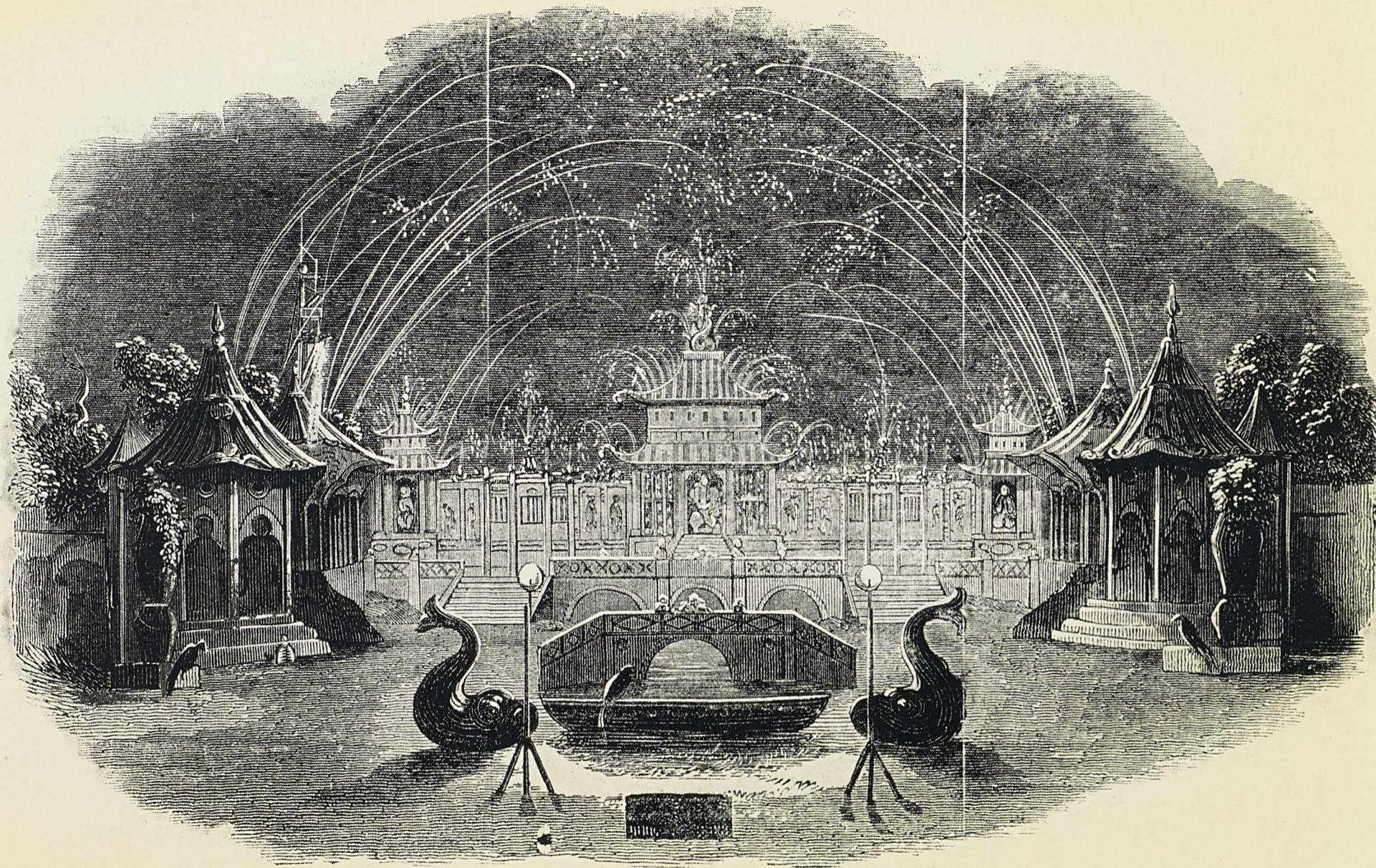
Rossi and Tessier, the pyrotechnists of Ranelagh, gave displays at the Bermondsey Spa Gardens in 1792. A representation of the Siege of Gibraltar was given, and on September 28th of that year, "by special desire the Battle of the Fiery Dragons, and the line comet to come from the Rock of Gibraltar and cause the Dragons to engage." Brock also gave displays here later.

Finch's Grotto Gardens, whose site is now occupied by the headquarters of the Metropolitan Fire Brigade in Southwark, had occasional displays of fireworks about 1770, as did the Temple of Flora in the Westminster Bridge Road, about the same date. Clithero advertised a display of fireworks at Jamaica House, Rotherhithe, in 1762.

A Peace Celebration display is announced for February 7th, 1749, to "be play'd off this evening in the Field adjoining to the Tavern called Bob's Hall."

In 1788 Astley senior advertises, to take place at the Royal Grove and Astley's Amphitheatre, Westminster Bridge, a "Double Display of Fire-Works Numerous Devices prepared in the usual way from Powder, etc., which will be alternatively played off with the new-invented Philosophical Fire-Works, under the direction of Mons. Henry, the inventor and Professor of Natural Philosophy from Paris."

The same year he announces a display "on the Thames immediately after Astley's Exhibition in Honour of His



Firework Temple at Vauxhall, 1845. From a woodcut in "The Illustrated London News."

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Majesty's Birth-day," and concludes by saying "the Fireworks are made under the Direction of Mr. Astley, by Messrs. Cobonell & Son, who will let them off on the Thames this evening at different signals from Mr. Astley, Sen., who will be mounted on the Gibraltar Charger, placed in a Barge, in the Front of the line of Fireworks."

The "Philosophical fireworks" above mentioned were evidently an imitation of those exhibited at the Lyceum by Diller, which he describes as "Philosophical Fireworks from Inflammable Air without smell, smoke or Detonation." These appear to have been nothing more than gas jets arranged in patterns and designs, some revolving and some stationary. Air was forced from a bladder through a sponge saturated with ether. Movement and variation were produced by turning on and off the gas from separate sets of holes. Two colours only appear to have been produced—rose and green; these were by the addition of strontia and baryta or copper.

A handbill is in existence advertising a similar display at Hull in 1804, by W. Clarke.

During the early part of the nineteenth century several gardens round London made a feature of pyrotechnic displays. The Mermaid Gardens, Hackney, in "The Morning Chronicle" of June 1st, 1812, announces "the greatest feast for the eye ever exhibited is a superb firework by that unparalleled artist, Mr. Brock, Engineer."

The Yorkshire Stingo and Bayswater Tea Gardens in the west gave displays up to the early forties. White Conduit House, in the Islington district, had firework displays from 1824 up to shortly before the closing of these gardens in 1849.

Rosherville Gardens, opened in 1837, the North Woolwich Gardens, the Eagle, 1825-82, the Globe, Mile End, the Cremorne, 1843-77, all had their firework displays. The best

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known, however, for this feature were the Surrey Zoological Gardens, 1831-56, where Southby, of Vauxhall, conducted displays for several years, producing pyrotechnic and scenic displays there. In 1841 he gave a reproduction of the fireworks of St. Angelo, and the Illumination of St. Peter's, Rome, which proved a great attraction to the gardens.

In the provinces the Belvue Gardens, Manchester, and the Clifton Zoological Gardens, Bristol, have made a feature of firework displays in their list of attractions, those at the latter being carried out in 1835 by Gyngell.

The famous Cremorne Gardens made a feature of pyrotechnic displays and spectacles of the scenic type with more or less regularity from their opening in 1846 down to the final closing owing to public petition in 1877. The earlier displays were carried out by Mortram and Duffel.

Firework displays of a somewhat more ambitious nature have been given from time to time at the Alexandra Palace, no doubt in emulation of the historic Crystal Palace displays, which are dealt with in the ensuing chapter.

CHAPTER VI

FIREWORKS IN THE NINETEENTH & TWENTIETH CENTURIES

AS we have seen, the commencement of the eighteenth century was marked by great activity in the pyrotechnic art.

Firework displays were looked upon as a necessary item in the programme of a place of public entertainment. So ambitious did these displays become, owing to keen rivalry existing between the various resorts, that any official display in celebration of peace or like event must of necessity be on a scale of unexampled lavishness.

No official display of note appears to have been given in London during the first thirteen years of the nineteenth century, or indeed since the Aix-la-Chapelle peace display. The reason may have been the public outcry on the score of waste on that occasion.

They were totally prohibited at the coronation of George III, and at his jubilee in 1809 there were apparently no firework displays in London, although more than forty towns about the country celebrated the event pyrotechnically, and a fine display was given from the Fleet at the Nore.

The largest public firework exhibition on this occasion was that given at Bombay, where the celebration took place earlier in the year, the date selected being June 4th, the King's birthday, instead of October 25th, the actual anniversary of his accession.

The Peace of 1802, although no official display was given, was the occasion of much private pyrotechnic enterprise, the fireworks and illuminations in London lasting nearly a week.

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The Peace of 1814 was signalised in London by several displays: the 1st of August was chosen for the Peace Celebration, it being the centenary of the accession of the House of Brunswick, and also the anniversary of the Battle of the Nile.

The display in Hyde Park commenced with a naval engagement on the Serpentine between model warships representing the English and the combined French and American Fleets. This item, which lasted three hours, was followed by a display of water fireworks. The display in Green Park commenced at ten o'clock, one of the chief items being the "grand metamorphosis of the Castle into the Temple of Concord." This change, says a writer in "The Times" of the period, "was made with somewhat less celerity than those witnessed in our theatrical pantomimes. It resembled rather the cautious removal of a screen than the sudden leap into a new shape. When fully developed, however, it presented a spectacle which excited general approbation."

The Temple of Concord was an elaborate structure illuminated with coloured lamps, and decorated with gilding, festoons, etc., and transparent paintings. It was designed by Smirke, the paintings being by Stodard, Howard, Hilton, and others, and represented such subjects as "The Golden Age," and "Peace restored to Earth."

Charles Lamb, in a letter to William Wordsworth, dated August 9th, 1814, after describing the havoc wrought in the park by the crowds and booths, remarks that: "After all the fireworks were splendid—the Rockets in clusters, in trees and all shapes, spreading about like young stars in the making floundering about in space (like unbroke horses) till some of Newton's calculations should fix them, but then they went out. Anyone who could see 'em and the still finer showers of gloomy rain fire that fell sulkily and angrily from

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'em, and could go to bed without dreaming of the Last Day, must be as hardened an Atheist as * * * *."

St. James's Park was reserved for those who paid for admission. The trees were illuminated with lamps, and a Chinese bridge, which had been erected over the lake, was similarly treated. The use of gas on this structure must be one of the earliest occasions of its being employed for outdoor illuminations of this nature. Neither can the result be considered altogether successful, as the building caught fire towards the end of the firework display, and a lamplighter, who appears to have been caught by the flames in an attempt to throw himself into the water, was killed. Other men similarly employed were also severely burned. These men, evidently through ignorance, had started lighting the lower lamps first, working upwards on the structure, until they found themselves in a position of intolerable heat with no means of descending.

The pyrotechnic display consisted chiefly of aerial fireworks with gerbs, roman candles, fountains, and wheels; there do not appear to have been many devices of any size. "The Times" reporter complains that "the repetition of these things, with occasional pauses, for more than two hours became tedious to all."

The coronation of George IV, in 1821, was celebrated by a display in Hyde Park, including land and water fireworks, superintended by Congreve. The displays on the coronation of William IV, in 1831, were directed by Congreve's successor, Sir Augustus Frazer, but appear to have been of an insignificant character.

Queen Victoria's coronation was celebrated by displays in Hyde Park and Green Park, conducted by Southby and D'Ernst, which exhibitions included a Temple on similar lines to that of 1814.

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In France, during the first few years of the nineteenth century, there were many pyrotechnic displays of importance. Napoleon is credited with being extremely partial to such exhibitions. Displays took place in Paris in the Champs Elysées, at the barriere Chaillot, before Les Invalides in 1801 to celebrate the foundation of the Republic, and in the following year in honour of Napoleon's arrival in that city.

Major-General Lord Blayney, who was captured by Napoleon's troops in the Peninsula in 1810, travelled on parole across Spain and France on his way to Verdun. His somewhat leisurely journey of nearly six months enabled him to witness many celebrations of French victories in the towns through which he passed. He records having seen fireworks and illuminations among other places at Malaga and Orleans.

In 1804 a display was given by Napoleon before the Hotel de Ville, Paris, on his assumption of the title of Emperor of the French. The scenery provided for this display took the form of a representation of Mount St. Bernard, with a figure symbolising Napoleon mounted on a charger on the summit.

This display was repeated in 1810 on the occasion of his marriage with Marie Louise ; this time, however, the top-most feature was the Temple of Hymen, with figures of Napoleon and his bride.

Other displays were given on the bridge of Louis XVI, which appears to have been a popular position for such exhibitions, in 1800, 1804, 1806, 1820, and 1821. Another site frequently used for displays was the garden of the Senate, where Ruggieri fired displays in the years 1801, 1806 (twice), and 1807.

Fireworks continued to be a national institution in France, irrespective of the form of government. Louis Napoleon, like his uncle, being fond of fireworks, or it may be, considering

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them a good means of gaining popularity, made any public event an excuse for pyrotechnic displays. Notable occasions were the Military Fetes, 1852, the Fete of the Emperor, 1853, the visit of Queen Victoria to the Paris Exhibition of 1855, in honour of which a most elaborate display was given at Versailles, the Baptismal Fetes in 1856, the triumphal entry and the Emperor's birthday, 1859, and the visit of the King Consort of Spain in 1864.

The Entente Cordiale movement in 1868 was responsible for displays in the Fleets on both sides of the Channel, those in France taking place in Cherbourg, those in England at Spithead.

A previous event which had been celebrated pyrotechnically on a large scale in both countries was the Peace Rejoicing at the conclusion of the Crimean War.

This occasion was marked in London by four displays of fireworks on a scale hitherto unprecedented. The sites chosen were Hyde Park, Green Park, Primrose Hill, and Victoria Park. They were arranged thus with the very sensible idea of splitting the crowds of sightseers into sections and thus preventing dangerous crowding to one spot. The fireworks were prepared for these displays in Woolwich Arsenal, under the direction of Mr. Southby, the pyrotechnist of the Surrey Gardens, who went there for this event.

The programmes of these displays were precisely similar, with the exception of that at Primrose Hill, which consisted mainly of aerial fireworks.

Tyrrell, in his "History of the War with Russia," gives the following account of the display in Green Park: "At the appointed signal there was a continuous discharge of maroons, accompanied by brilliant illuminations with white, red, green, and yellow fires. . . . Then for two hours followed every conceivable design of elegant and dazzling pyrotechnic

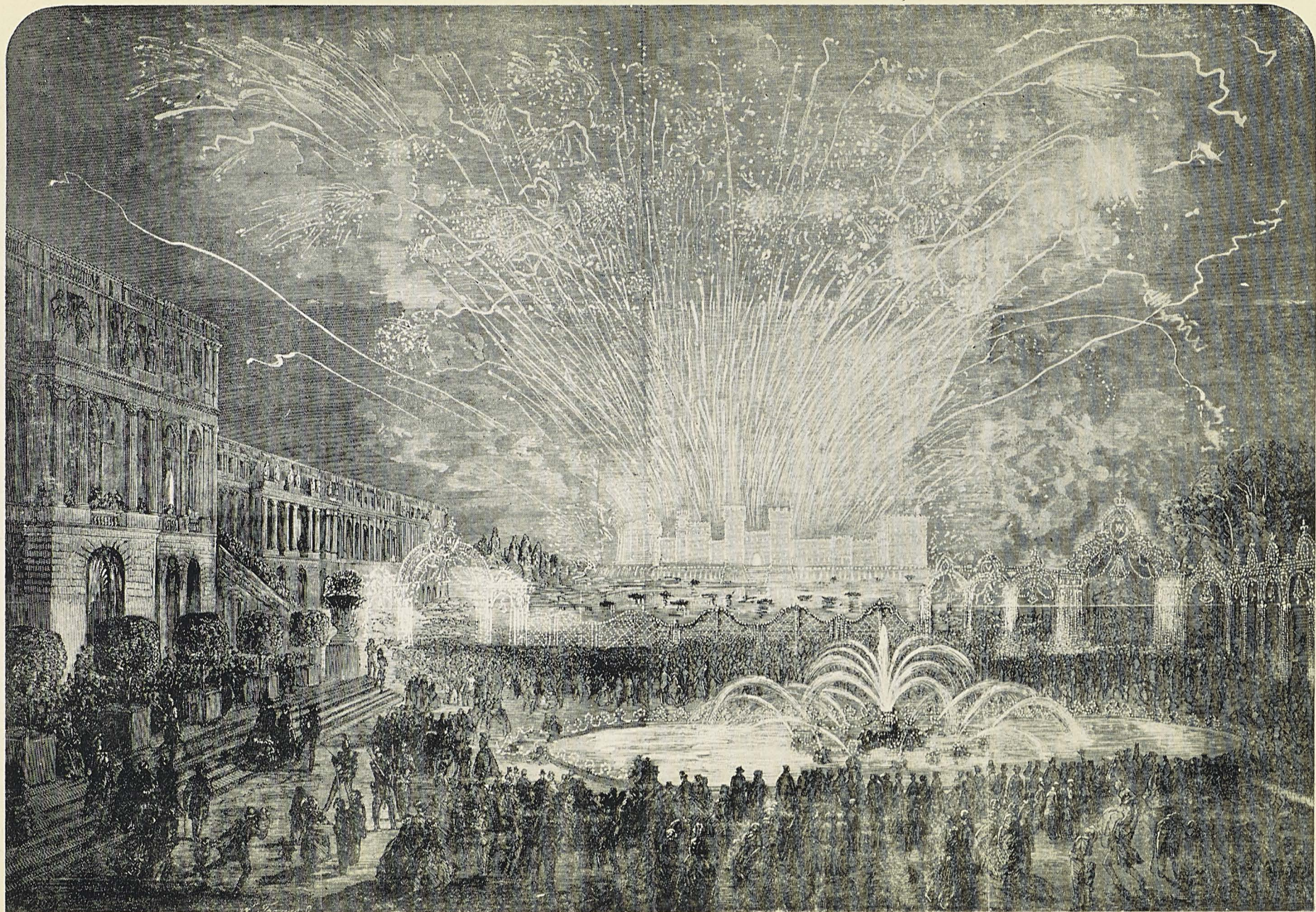
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art. Flights of rockets a hundred at a time ; revolving wheels, sun star and golden streamers, and fiery serpents chasing each other through the air. Gerbs, Roman candles, tourbillions, shells, and fixed pieces of the most fantastic designs and brilliant hues. The eyes were dazzled by the intensity of the light. . . . It was strange to believe that so fierce and ungovernable an element as fire could be rendered so delicately obedient to the will of man. . . . The triumph, however, of the entertainment was reserved for the close of it. This was a tremendous bombardment, during which the air was constantly filled with flights of rockets, and was intended as a representation of the last grand attack upon Sebastopol—the blowing up of the magazines and works, and general conflagration.

“ As an introduction to this there were five fixed pieces, all of complicated construction, the centre being an enormous one which, amid all its fantastic blazing and revolving, exhibited the words ‘ God Save the Queen.’ Language fails to convey a vivid idea of the deafening, roaring, crashing and grand appearance of the termination, during which the proud fortifications of Sebastopol were supposed to succumb. Then rose up into the blackness, rapidly one after another, six flights of rockets, comprising altogether no less than ten thousand of these beautiful and brilliant instruments. . . . It was such a spectacle as man could not reasonably expect to witness more than once in a lifetime.”

This account appears to be somewhat highly coloured, as the official programme makes no reference to the fall of Sebastopol, but it is evident from it that the writer was greatly impressed with the display, and contemporary prints indicate that he was voicing popular opinion.

It is worthy of note that these celebrations were the first occasion of the kind in which the exhibitions consisted of



Queen Victoria's Visit to France, 1855. The Fireworks at Versailles. From a drawing by Gustav Doré in "The Illustrated London News."

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veritable fireworks without extraneous matter in the form of scenery and buildings. This may account for the fact that there was, on this occasion, considerably less of the usual outcry against the "waste" involved. It is curious that on occasions of this kind there are always to be found certain damp spirits who begin a clamour against the expenditure of money on fireworks which might be applied to other objects. The Aix-la-Chapelle display excited these gentlemen to a great pitch, probably on account of the elaborate nature of the preparations, which, as we have already seen, occupied over five months, thus providing them with plenty of time to develop their theme, or an object lesson to prove their statements.

Where, however, the display consists—as on the occasion under consideration—solely of fireworks proper, a few days' preparation on the actual site is usually sufficient; the kill-joy has less time to spread himself. It may be mentioned his season is over with the display; generally the British public, having enjoyed itself, turns a deaf ear to those who would convince it that it ought not to have done so.

Other displays took place in various parts of the kingdom: in Edinburgh on Arthur's Seat, at Portsmouth on the Fleet, to mention two only.

An interesting event which took place on the 25th August was the entertainment of 2,000 men of the Guards at the Surrey Gardens. This resort was at the time the home of British pyrotechny, the displays being conducted by Southby, who, as we have said, went into Woolwich Arsenal to assist in the production of the fireworks for the official displays. The amusements of the day concluded with an exhibition of fireworks.

A further event connected with the foregoing celebration was the festivities in Moscow on the occasion of the coronation

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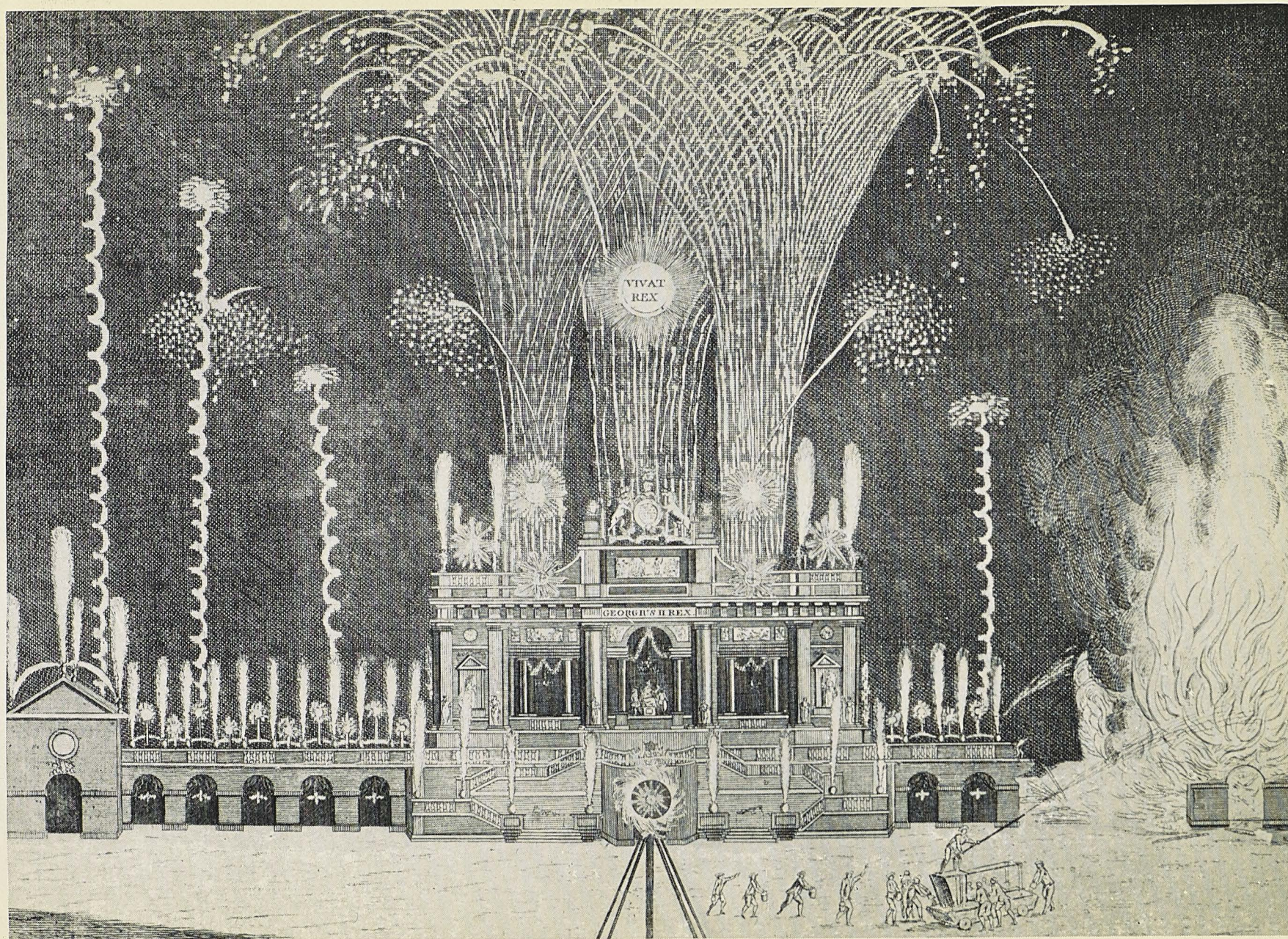
of the Emperor Alexander II, which concluded with a pyrotechnic display.

From this time until the end of the century the history of pyrotechny in this country is practically the history of pyrotechny at the Crystal Palace ; it has been the Crystal Palace displays which have set the pace, as it were, to pyrotechnists in this country, and has provided the spur which has placed British pyrotechnists not only ahead but markedly ahead of their competitors in other countries.

The Crystal Palace displays became a national institution, and any public event worthy of such recognition was accorded a pyrotechnic celebration there on a scale hitherto unattempted.

The credit for the original introduction of fireworks at the Crystal Palace must belong to the late C. T. Brock, who succeeded in inducing the Directors to institute a competition among pyrotechnists in 1865. It may be interesting to give in his own words an account of the matter, taken from an article written by him some few years later :

“ It occurred to me that of all the places of public resort suitable for the inauguration of a new era for pyrotechny, none offered such glorious advantages as the Crystal Palace, then at the height of its popularity. Its terraces, fountains and foliage offered unrivalled advantages for the display of grand effects. The Directors of the Crystal Palace Company, who had more than once been applied to for permission to hold displays in the grounds, feared that, inasmuch as fireworks had been recently associated solely with gardens of the Cremorne class, the Palace itself would be degraded to the same rank if consent were granted. I urged that the Exhibition of 1862 had afforded no opportunity for competition among firework makers—necessarily excluded by the nature of their trade—although almost every other



The GRAND WHIM for POSTERITY to Laugh at :
Being the Night View of the ROYAL FIREWORKS, as Exhibited in the Green Park, St. James's, with the Right Wing on Fire.

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branch of manufactures were embraced, that such a contest might with reason and advantage be held at Sydenham, and that fireworks were really not of an immoral tendency. I further agreed that in the event of the result being unfavourable, either financially or from a social point of view, no second display need take place, but if, as I felt confident, there should be a large attendance of the better classes, then other exhibitions might follow. The Directors, after many months of delay, consented to make the experiment, and the favourable result of the trial on July 12th, 1865, far exceeded my most sanguine expectations.

“The result was an unlooked-for success, 20,000 people being present on the occasion. Three more displays took place that year upon a small scale, but always with successful results.

“The first display was produced jointly by my father and Mr. Southby, the winner of the first prize, and continued to the end of that season by my father alone under my management.

“The success of fireworks at the Crystal Palace having become an accomplished fact, I built extensive works at Nunhead, and commenced manufacturing on a scale never previously dreamt of in the trade—the vast expanse of the locale of my displays obviously necessitating extraordinary expenditure of material.

“By degrees the set pieces grew from twelve feet in diameter to 300 feet. Shells for which the Crystal Palace has been renowned grew to one hundred times more than the ordinary shells of my early days, and thousands of pounds weight of material was gradually introduced to increase the effectiveness of these displays.”

The Crystal Palace displays carried out by C. T. Brock

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and his brother, Arthur Brock, who succeeded him in the business on March 25th, 1881, have since become proverbial. They continued up to 1910, when the Crystal Palace was taken over by the promoters of the Pageant of Empire. They have been revived in 1920, when the War Museum was opened, and the attendance has proved that the public taste for fireworks is very far from diminishing.

During the run of forty-five consecutive years an installation was built up, method and technique were evolved unknown in any other place of pyrotechnic exhibition.

While the firework terrace, with its magnificent background of park and shrubberies, is unrivalled as a firing ground, it is at the same time the most exacting. The huge building, its imposing position and setting, the wonderful fountains, all demand pyrotechnic effects on a corresponding scale.

The pictorial set pieces, originally introduced by C. T. Brock in 1875, increased in size until a plant was arrived at capable of exhibiting a picture ninety feet high and two hundred feet long on the main girder, which length could be extended to even six hundred feet of frontage, as on the occasion of the exhibition of a battle piece or similar subject.

During this period the subjects dealt with in the main set pieces have covered a wide range. A favourite subject, and one lending itself particularly well to pyrotechnic production, is the sea battle. Almost every historic naval engagement of sufficient size to warrant its adoption has been proved the subject for a fire picture.

Among the battle pictures produced are the following :— Bombardment of Alexandria in 1882, Siege of Gibraltar in 1883, Battle of Trafalgar in 1884 ; during 1885, two pictures representing the use of the ironclads of the period and based on the Naval manœuvres, entitled the “ Attack on Dover,”

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and the Battle of Bantry Bay ; the following year another imaginary picture depicting an attack by torpedo boats on the latest battleship, the "Colossus." The Bombardment of Sebastopol was reproduced in 1887, followed by the Jubilee Naval Review at Spithead. In 1888 the defeat of the Spanish Armada was depicted ; in 1890 Trafalgar, followed in 1891 by the engagement between the "Chesapeake" and the "Shannon," together with a portrait of Admiral Sir Provo Wallis, then aged one hundred, and another from an early painting showing him at the time of the engagement when the command of the English vessel devolved upon him owing to the casualties among the senior officers. Later in that year the Battle of the Nile was reproduced ; 1893 saw the Bombardment of Canton ; 1894 the Battle of the First of June, and the Battle of the Yalu. The Battle of Manilla Bay was produced in 1898, and on the centenary date the Battle of the Nile. In 1889, H.M.S. "Implacable" was shown in action on the day on which she was commissioned, followed in 1900 by the Bombardment of the Taku Forts, and in 1901 by the immortal sea fight between the "Revenge" and the "Fifty-three." In 1904 the Russo-Japanese War gave subjects in the various attacks on Port Arthur and the Battle of Tsu-Shima, and the Battle of the Sea of Japan in the year following. The Battle of Trafalgar was renewed that season, and in 1908 another imaginary picture portraying modern naval warfare was produced, followed in 1909 by an imaginary encounter between the first Dreadnought and other craft.

The revival of the Crystal Palace displays in 1920 saw the reproduction of the Battle of Jutland, of which the following appreciation appeared in the Press :

"The chief set piece in the programme is a Fire Picture of the Battle of Jutland, the most realistic spectacle ever

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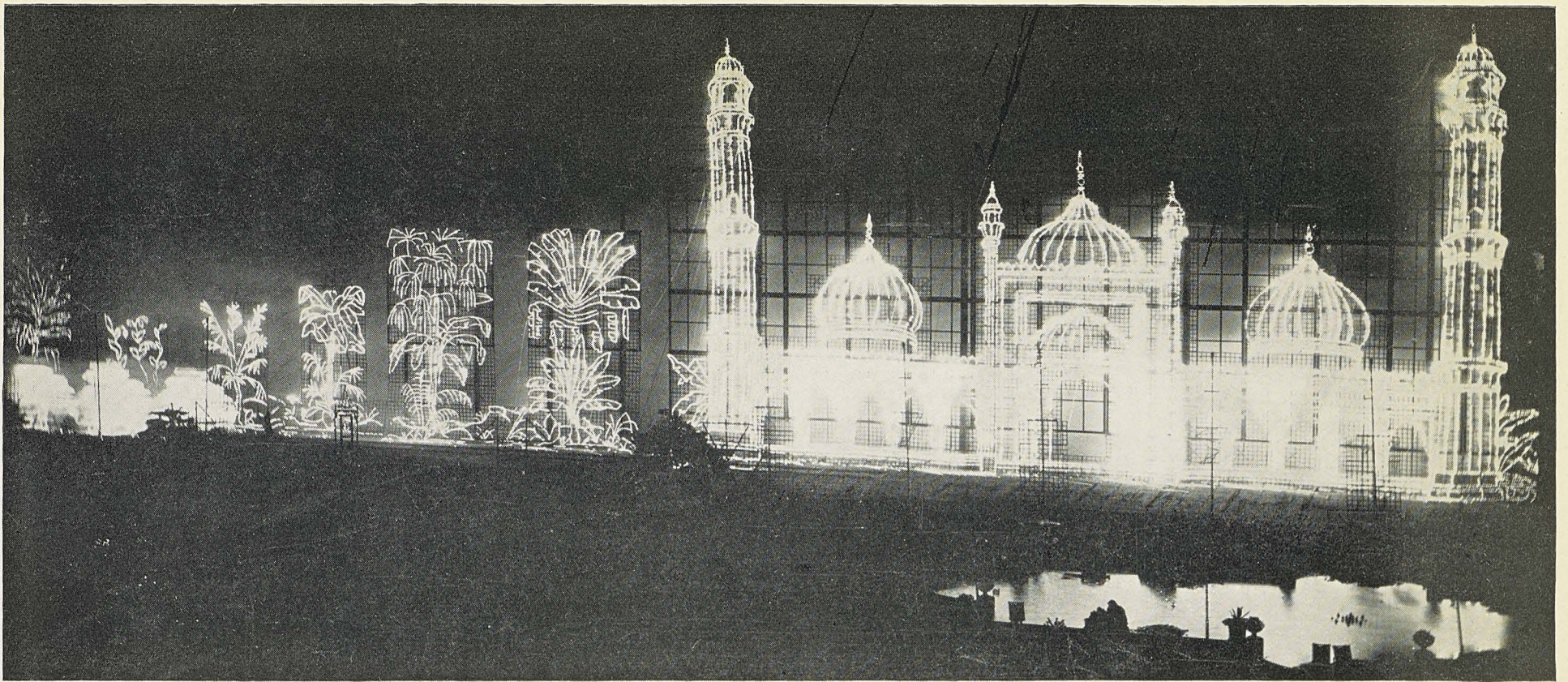
produced in fire ; by ingenious devices the guns fire, shells burst in all directions, gaping holes appear in the sides and upper works of the ships engaged, until—when the din of battle has reached its height—the German cruiser ‘Lutzow’ blows up and sinks. One realises that here at least is one pictorial subject in which the Cinematograph is hopelessly outdone ; the variety of noises, varying from the sharp bark of quick-firers to the boom of the heavy guns, which are here so wonderfully reproduced, are quite inadequately rendered by the conventional thumps on the big drum in the orchestra.”

Before the resources of lance-work were fully understood, the reproduction of famous buildings was a fruitful source of subjects ; those reproduced vary from the Crystal Palace itself to Worcester and Salisbury Cathedrals, and from the Arc de Triomphe to the Mosque at Delhi.

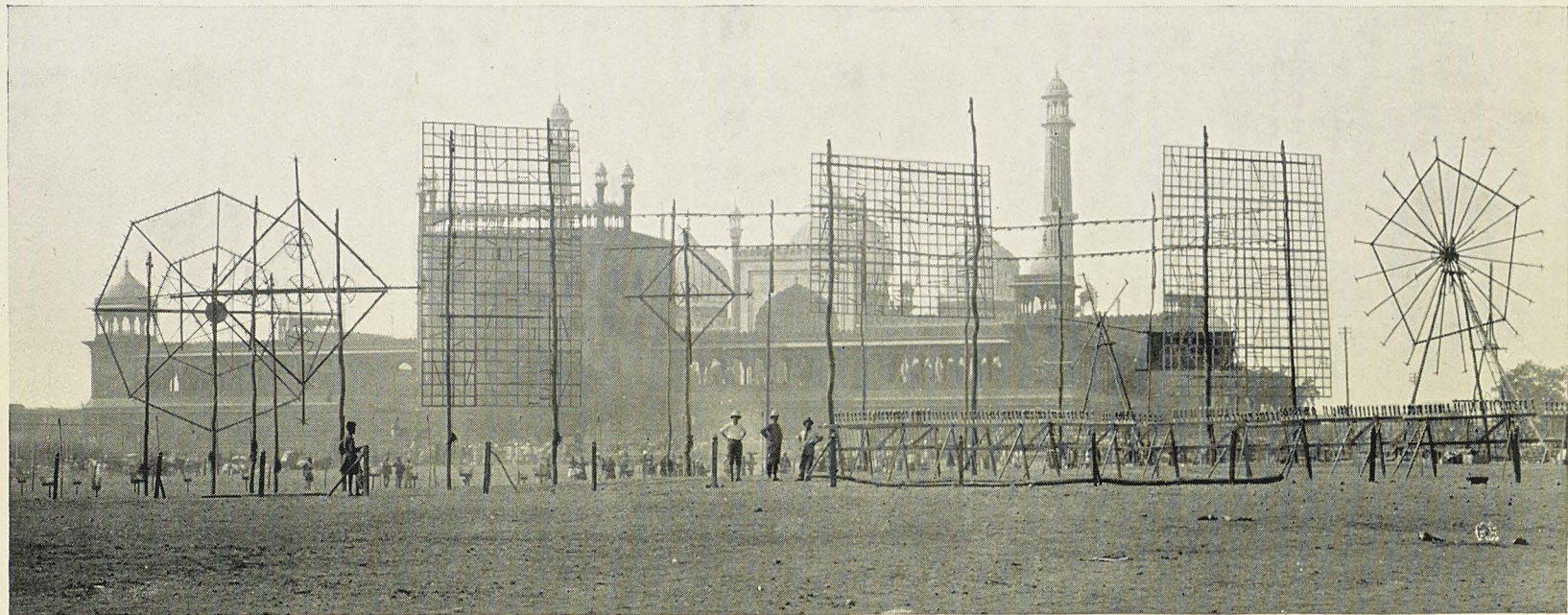
Natural catastrophes such as the Avalanche, the Eruption of Vesuvius, and the Destruction of Pompeii have been portrayed. The Wreck of the Eider in 1892, with the rescue of the passengers by the lifeboats, formed the subject of a popular set piece ; another successful scenic showed a wreck with line-throwing rockets and transport of passengers by the breeches buoy.

In 1879 portraits in fire were reproduced for the first time, and since that date those executed have included almost all the Royal Personages of the day, many of which have been fired electrically from the Royal Box by the originals. Other eminent people reproduced range from King Cetewayo in 1882, the Maori King in 1884, Li-Hung-Chang in 1896, to Douglas Fairbanks and Mary Pickford in 1920.

In 1887 what is known as the transformation set piece was introduced. Upon lighting, the piece exhibits a floral design in



A full-size picture of the Jumma Musjid in Fireworks at the Crystal Palace, 1892.



Firework Display for the Coronation Durbar at Delhi, January 3rd, 1903. In the background is the Jumma Musjid,

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colours, which, after burning some time, becomes transformed into a portrait, the lines of which are worked inconspicuously with those of the floral design, and, to use a modern term, camouflaged by its colours, the colour of the portrait being white.

The first portrait to be so shown was Lord Beaconsfield, the floral design being of primroses, and the occasion Primrose Day. This, for the first example of its kind, was very successful, and later in the year an enormous transformation picture, 200 feet long and 100 feet high, was fired at the Jubilee display, changing to portraits of Queen Victoria and members of the Royal Family.

A popular picture of this kind is the puzzle picture which transforms from a jungle scene to animals.

Another most successful changing picture was entitled "The Seasons," first produced in 1889, and revived from time to time. A rural scene changes from Spring to Summer, from Summer to Autumn, and finally to Winter. The effect is produced by varying compositions in the lances, and by employing lances of varying length, and requires very exact manipulation and supervision.

Patriotic, congratulatory, and political cartoons and devices have been exhibited in wonderful variety of design, sentiment, and language : Chinese, Persian, and Maori, to mention only three of the latter.

Living Fireworks, invented and patented by C. T. Brock and Co., in 1888, have always been a favourite feature of the Crystal Palace displays. The performer is clad in overalls of asbestos cloth, and on the side nearest to the spectators wears a light wood framework, of which the outline is "lanced" to depict the particular character to be portrayed.

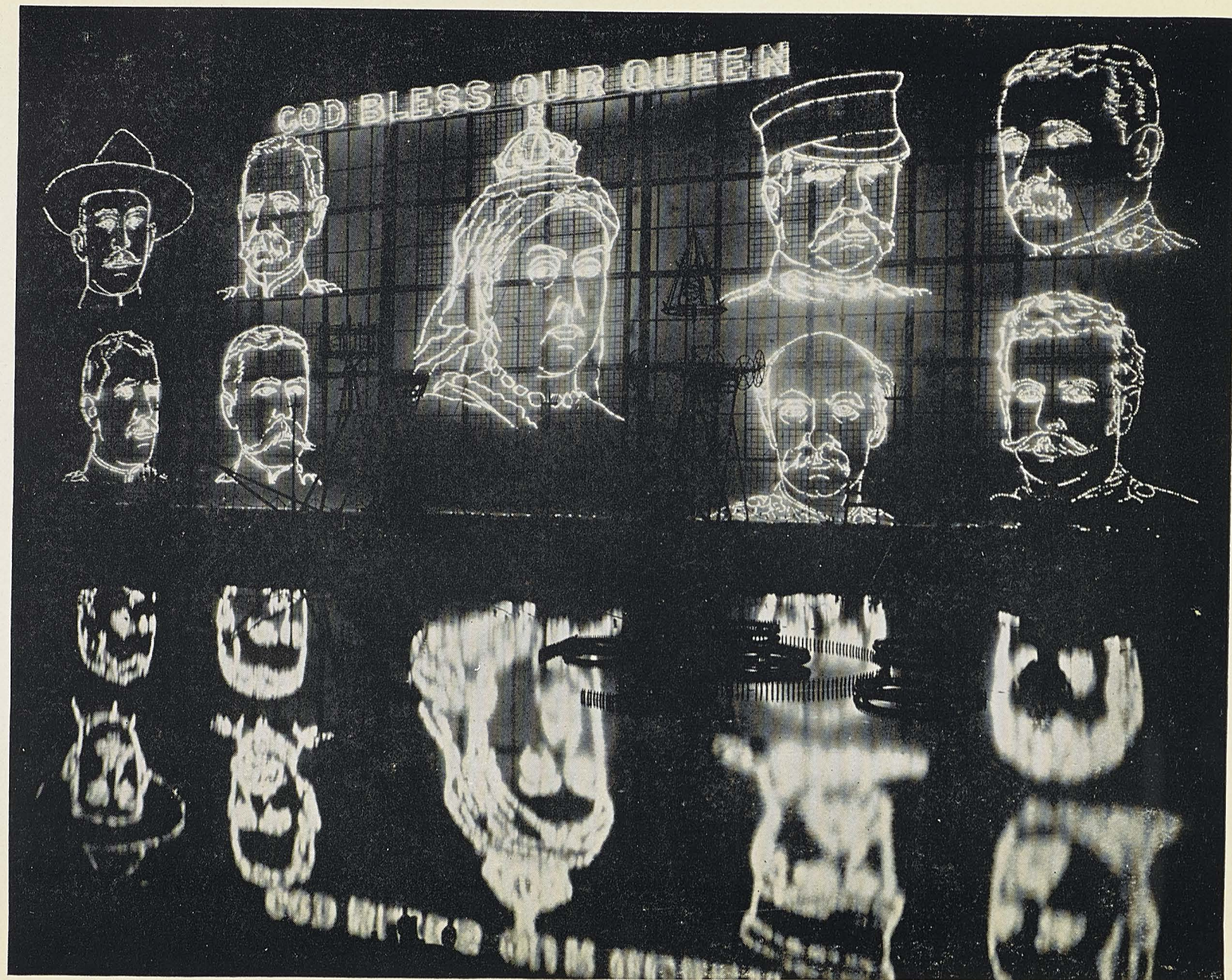
The first subject dealt with was the boxing match, which has enjoyed continuous popularity up to the present day, and is possibly the most successful.

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Other favourites have been Blondin on the tight rope, inspired by the appearance of the real Blondin on the firework terrace, surrounded by firework effects, in 1871; dancers of various kinds, from the Sailor's Hornpipe to Salome; Cat fights; Cock fights; the Boxing Kangaroo in 1893, when that performance was attracting crowds to the old Aquarium; an Indian Snake Charmer; a Fisherman; a Trapeze Artist, have all been produced by living actors in fire.

In 1895 "The Village Blacksmith" was enacted, with horse, blacksmith, assistant, and horse's owner, with forge, bellows, anvil, and all necessary "properties." The following year a piece was exhibited showing various members of the building trades at work. Then followed the Fire Scene, in which a house is seen on fire, the motor fire engine arrives, the men jump down, unroll the hose, and proceed to extinguish the outbreak with a jet of fire. Another ambitious effort showed a City policeman regulating the traffic. The most elaborate scene of the kind yet attempted was to work living figures in connection with the main set piece. The subject chosen was life in the Arctic Regions, and opened with the open Polar Sea, with whaling vessels, spouting whale, and launch of the whaling boat, which follows the whale and fires a harpoon. The picture then changed to Arctic winter, ice forms, and the vessel is frozen with the ice, sledging parties travel over the ice, and the picture concluded with a man and bear fight in living fireworks. The same year—1890—there was introduced into the Children's Fireworks, which form an annual feature of the Crystal Palace displays, a living Jack and the Beanstalk picture.

In 1906 the then popular song, "I wouldn't leave my little Wooden Hut for You," was the basis of what was described in the programme as a Living Firework Drama.



A Crystal Palace Set Piece at the time of the South African War. (200 ft. long by 70 ft. high.)

NINETEENTH AND TWENTIETH CENTURIES

The popular songs of the day have provided the subject for many successful set pieces, and form a class of picture which derives much of its success from the band accompaniment and the opportunity for vocal effort on the part of the crowd.

The origin of this type of picture is worth recording. In 1889 the Shah of Persia visited the Crystal Palace, and fired a portrait of himself, electrically, from the Royal Box. A popular song of the day, "Have you seen the Shah?" was suggested to some musically inclined members of the audience, who commenced to sing it, and were soon joined by the whole of the spectators, numbering about 50,000.

The effect of this impromptu concert was so striking as to lead to the production of the popular song whenever there happened to be one suitable for pictorial rendering in fireworks.

In 1892 a mechanical Lottie Collins, 60 feet high, dancing to the then popular strain of "Ta-ra-ra-bom-de-ay," was enthusiastically received. A series of patriotic and sentimental songs at the time of the South African War, as "The Absent-minded Beggar" and "Good-bye, Dolly Grey," etc., were very successful. The "Honeysuckle and the Bee" provided the subject for a transformation picture, a design of honeysuckle changing to a girl's head with a mechanical bee twelve feet long.

In 1908 three songs were included in one piece—"Bill Bailey," "Farewell, my Bluebell," and "The Old Bull and Bush."

The smaller mechanical pieces form a history of locomotion during the half-century covered by the displays. Bicycles, motor cars, looping the loop, aeroplanes, costers' barrows, hansom cabs, fire engines, scooters have all been represented, and in 1895, on the occasion of the visit of the Railway Conference, two of the best mechanical pieces ever

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carried out—full-sized representations of the “ Rocket ” and the latest type of express engine with exact details and working parts.

An effective working device introduced as early as 1870 was a comet travelling down a wire from one of the famous towers to the ground. Later the comet was replaced by a dragon, Mother Goose, and in 1872 by a “ Fiery Bicycle,” a subject which seems somewhat out of place in such a position. The next development of this feature was to introduce a living man who, clad in shining armour and surrounded and illuminated by a frame of fireworks, striking an impressive attitude, slid from the summit of the tower to the terrace.

The name of this performer, no doubt in imitation of the Italian artists who on a smaller scale carried out a similar feat at Vauxhall, was given in the programme as Signor Gregorini. In private life or in the works, however, he went by the name of Bill Gregory, and it is recorded that, when on the first night he stuck half-way down and had to remain in his airy position for the remainder of the display, his remarks left no doubt as to the country of his origin.

It is characteristic of Mr. C. T. Brock that he who originated the idea was the first to try the descent. The weight of the cable was very considerable and the strain very heavy in order to keep it sufficiently taut, and doubts were expressed as to the advisability of putting such a stress on the structure, which led to the abandonment of the performance.

It would be tedious to attempt to give anything like a description of the many and varied moving and stationary devices used in the Crystal Palace displays. The descriptions in the traditional somewhat flowery language of the firework programmes would convey little without illustration. One feature generally to be found in the programme is that of the wheels. These are generally fired in a group of three in the

NINETEENTH AND TWENTIETH CENTURIES

centre of the Terrace, the designs varying in form, movement and colour from time to time, the fire of the centre or largest wheel forming a circle one hundred feet in diameter.

The historical displays during this period include the displays given in India in 1875-6, during the tour of King Edward, then Prince of Wales, at Bombay, Madura, Colombo, Madras, and Jaipur, and a series of enormous displays carried out at the Philadelphia Centennial Exposition in 1876, at one of which 250,000 people paid half-a-dollar admission, and in 1877, the displays given at Calcutta and Delhi on the occasion of the assumption by Queen Victoria of the title Empress of India.

The Jubilee and Diamond Jubilee of Queen Victoria produced enormous activity in the manufacture of fireworks. Displays great and small took place all over the United Kingdom, or rather, the Empire.

Among the displays fired on the occasion of the Diamond Jubilee, certainly not the least interesting, although comparatively small in extent, was that given at Blantyre in the heart of the African continent. This display, which included a portrait of Her late Majesty, was carried up three hundred and sixty miles of the Zambesi, thence by canoe over eighty miles of sandbanks and mud, and finally thirty miles overland with a rise of 3,500 feet.

Other displays were the display on the Tagus in 1886 on the occasion of the marriage of the late King of Portugal ; the display fired from Brooklyn Bridge for the Columbus Tercentenary in 1892 ; the Imperial Fete on the Danube in 1903 ; the display fired from thirteen battleships moored at a distance of a quarter of a mile from each other on the occasion of the "Entente Cordiale" visit of the French Fleet in 1905 ; the display celebrating the Tercentenary of the founding of Quebec in 1908 ; and the greatest display of fireworks

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ever fired—the official Peace display in Hyde Park in 1919, in which some of the ground works suffered from the rain which, unfortunately, started about five o'clock, but the aerial work was on an unprecedented scale, shells varying from sixteen inches down to $5\frac{1}{2}$ inches in diameter being fired in salvoes of twenty-five to one hundred.

Rockets of 1 lb. were fired in flights of one hundred, and a final flight of three thousand; sets of Roman candles, each containing two hundred; one hundred fiery jets, etc., etc. The "Fourth of June" celebration at Eton has always been the occasion of a firework display, and displays have taken place annually, with the exception of the years of the Great War, from at least as early as the beginning of the nineteenth century. Hone, in his "Everyday Book" (1831), speaks of the fireworks as a well-established feature of the festival.

It is possible, and even probable, that they date from the reign of George III, on whose birthday the event takes place.



PANORAMA OF SOME OF THE AERIAL EFFECTS IN THE NATI



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PANORAMA OF SOME OF THE AERIAL EFFECTS IN THE NATIONAL FIREWORK DISPLAY AT HYDE PARK, 19th JULY, 1919.

CHAPTER VII

FIREWORK MANUFACTURE

THE manufacture of fireworks in this country, as an industry distinct from mere firework making, dates from the early part of the eighteenth century. Before that period displays appear to have been generally carried out by the military, or at any rate under the control of artillery or engineer officers. At that time the art was considered to have two distinct branches, civil and military pyrotechny, the latter class naturally attracting most attention during a period when Europe was almost continuously at war, and when firearms had made little progress from the early types.

As has been previously mentioned, Jones complains that when it was required to carry out a display of fireworks on a large scale, recourse was always had to foreigners to conduct it. One reason was that, apart from the actual making of the firework units, a display depends far more for its success on the experience and skill of the pyrotechnist in arranging and composing both the form and sequence of the pieces. The firework makers capable of carrying out a display on a large scale were very few ; there were fewer, if any, in this country. The whole of the trade was illegal ; under the statute of the 9th and 10th of William III it was illegal to make, sell, or let off fireworks :

“ By the 9th and 10th of William, Chap. 7, it is enacted : That if any Person shall make or cause to be made, or sell, give, or utter, or offer, or expose to sale any Squibs, Rockets, Serpents, or other Fire-works, he shall forfeit Five Pounds. And that if any Person shall permit the

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same to be fired from his House or Premises, or shall cast or fire, or be aiding and assisting in casting or firing the same in any public Street, House, Shop, River, or Highway, he shall forfeit Twenty Shillings, or be committed to the House of Correction to hard Labour for one Month."

This Act continued in force up to the passing of the Gunpowder Act in 1860. There were periods during which it was practically a dead letter, and again periods of sporadic activity.

The first restriction of the public use of fireworks appears to have been an order in council dated November 6th, 1685, which "For the preventing of Tumultuous Disorders" and with the object of "Disappointing the Evil Designs of Persons Disaffected to the Government, who commonly make use of such occasions to turn those Meetings into Riots and Tumults," enacted that "No Person or Persons whatsoever, do presume to make or encourage the making of any Bonfires, or other Publick Fire Works—without particular permission Leave in Order—upon Pain of His Majesty's Displeasure; and being Prosecuted with the utmost severity of the Law."

A notice appeared in the press of November 1st, 1788, dated from the "Public Office, Bow Street," warning the public against firing crackers in the street, and quoting the Act "that no Person may claim Ignorance thereof." Again, in 1814, "The Times" has an account of a summons under the Act of a William Swift, "for exposing for sale, Squibs, Serpents, Crackers and Fireworks of other descriptions to the great danger and annoyance of the public and contrary to the Statute." The report continues:

"Mr. Laws in opening the case observed, that this was a prosecution brought forward at the recommendation of

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the Magistrates of Union-Hall, who, however, did not by it seek to punish the defendant with severity but only to inform him and others acting like him, that the Act upon which the present indictment was founded and which so far back as the reign of William III, was passed for the protection of the public, though it had not lately been acted upon, was still in force. The defendant, it appeared, was a man of property and a respectable holder residing in Falcon-Court, where he had for some time past carried on the profession of a firework-maker. The officers of Union-Hall having heard, however, that he was in the habit of supplying boys or any person who applied indiscriminately with these dangerous commodities, they determined, if possible, to put a stop to this traffic, so dangerous to the public safety. For this purpose they sent a person, properly instructed, to purchase some ; Goff, Bruce, and some other of the officers remaining near the door to detect him coming out ; the purchase was made, and as the purchaser was quitting the house, the officers stopt him and forced their way in. They proceeded to search the premises, and concealed in closets and other parts, they discovered a vast quantity of fireworks of various sizes and descriptions, amounting to 19,600 and weighing upwards of 6 cwt., several of these, singly, were large enough to have spread ruin through the neighbourhood, had they by accident exploded. These the officers took away and deposited at the Office, where they still remained to the great annoyance of the Magistrates waiting the decision of this question."

Hone, in his "Everyday Book," records that at that time, 1825, "A Corporation notice was annually left at the house of every inhabitant in the City of London, previous to lord mayor's day." The following (delivered in St. Bride's) is its form :

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“ October the 11th, 1825.

Sir :

By Virtue of a Precept from my Lord Mayor, in order to prevent any Tumults and Riots that may happen on the Fifth of November, and the next ensuing Lord Mayor's Day, you are required to charge all your Servants and Lodgers, that they neither make, nor cause to be made, any Squibs, Serpents, Fire Balloons, or other Fireworks, nor fire, fling, nor throw them out of your House, Shop or Warehouse, or in the Streets of this City, on the Penalties contained in an Act of Parliament made in the Tenth year of the late King William.

Note. The Act was made perpetual, and is not expired, as some ignorantly suppose.

C. Puckeridge, *Beadle*.

Taylor, Printer, Basinghall Street.”

During the period of the operation of the Act, that is from the end of the seventeenth to the middle of the nineteenth centuries, on the occasion of public rejoicing, the authorities were in the anomalous position of employing persons to break the law, both by manufacturing and displaying fireworks.

Although, as we have seen, this Act had very little effect on the quantity of fireworks manufactured, it had considerable adverse effect on the industry. As the whole thing was illegal, no regulations were framed to control the making, storage, or distribution of fireworks, or the safety of either workers or public. The manufacture was conducted on lines which, at the present time, appear inconceivably reckless. Several people working in one room in a crowded building, with loose composition and gunpowder, and a fire in an open grate round which finished or partially finished goods were put to dry, and this in a thickly populated area of London.

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The result of this state of affairs, as might have been expected, was a continuous series of explosions of a more or less serious nature.

An early press account, dated 1722, relates to "Mr. Goodship of White Alley in Chancery Lane," and continues, "as he was making some fireworks, the Gunpowder took fire and blew him up, by which means the House was fired, and that adjoining somewhat damaged. More Mischief had been done, but that there was timely help. The Man is so hurt that his life is despaired of." Another account gives the man's name as Goodsheaf.

The early part of the nineteenth century provided an extraordinary list of accidents.

In 1810 we find the following account of an accident at Bath :

"On Monday a dreadful accident happened at Bath to Mrs. Invetto, a firework-maker, and a young man her assistant. They were preparing sky-rockets, etc., for the Jubilee, when, by some means, an explosion took place of a considerable quantity of powder, some say upwards of two hundred barrels, which blew the house, and another adjoining, to atoms. The unfortunate woman was miserably burnt and bruised ; and no hopes are entertained of her recovery. The poor fellow also lies in a shocking state at the Casualty Hospital at Bath."

In 1814 two accidents are recorded to Mortram and Clithero. The former took place in the "Westminster Roade, near the Asylum" ; a man and two boys were very badly burned, two succumbing to their injuries the same day. Clithero's establishment was situated in Fleet Street Hill, Bethnal Green. The accident here was caused by fire from the steam engine reaching some fireworks. Three people

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were badly injured, and much glass was destroyed in the neighbourhood. Clithero appears to have had his works separate from the dwelling-house, an arrangement which appears to be the exception rather than the rule. Mortram's premises were again destroyed in 1818, fortunately without loss of life.

A serious accident took place in 1815, in which five people lost their lives, the premises, and those on either side, being demolished, and nearly all windows destroyed within two hundred yards. The proprietor of the premises, which were situated at Wilkes Street, Spitalfields, was Lushalan.

In 1821 a third accident occurred at Mortram's works, the newspaper account of which gives an illuminating glimpse of the extraordinary methods of the period :

“ Tuesday morning an accident, which occasioned considerable alarm, and might have been attended with dangerous consequences, took place in the house of M. Mortram, firework-maker, in Westminster Road. It appears that one of the boys employed in making composition stars for rockets had placed a number of them on the fender before the fire to dry, and had set fire to one on the hob, which falling in amongst the others, the whole exploded, by which a little girl was much hurt in the back, and so frightened that she ran to the window of the first floor, but was prevented jumping out. The boy escaped up the area with his jacket on fire. The neighbours were now much alarmed, fearing that the fire might spread to more combustible matter in the house, and so on to the extensive workshops of Madame Hengler, the celebrated pyrotechnic to his Majesty ; but, through the activity of the workmen, who ran into the adjoining house with buckets of water, further damage was happily prevented, or the

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consequences might have been dreadful. An accident of a shocking nature, it will be recollected, occurred about three years since in the same person's repository, when two men were killed by the explosion."

In 1825, in Bell's "Weekly Messenger" of September 4th, appears the following account :

" DREADFUL EXPLOSION IN WHITECHAPEL.

" Yesterday morning, about half-past eight o'clock, Whitechapel Road, and the numerous streets that abound there, were thrown into the greatest state of agitation, by the inhabitants experiencing a most tremendous shock, as if caused by a volcano or an earthquake. The houses for a considerable distance were deserted by their inhabitants, and men, women, and children were seen running about in all directions, under the impression that the world was at an end. It was soon ascertained that their alarm was produced by the explosion of the factory of Mr. Brock, the artist in fireworks, at No. 11, Baker's Row, Whitechapel Road, nearly opposite the London Hospital.

" The following particulars relative to this direful disaster have reached us :—Mr. Brock has resided for the last five years in Baker's Row, and at the back of his dwelling-house is his repository for fireworks, where they are manufactured. This building is about 50 feet by 20 feet, and contains three magazines, which are lined with lead, and would be perfectly secure from fire, should it occur, on any of the adjoining premises. In these receptacles were deposited all the powder, composition, and, in fact, all the combustible matter, and Mr. B. was remarkable for the method he had taken to prevent any accident occurring on his premises. A few weeks since he had taken two boys out

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of the poor-house to instruct in the art of firework making, and he kept them chiefly employed in filling and ramming the cases of the sky-rockets, serpents, squibs, etc. The latter part of this stage of the work is done by a funnel, or piece of tin made in the shape of an extinguisher, and a small piece of iron wire, about a foot long, which is used as a ramrod. The small end, or nipple, as it is called, of the extinguisher is introduced into one end of the rocket or squib, and the boys ram the powder and wadding down with the ramrod. Yesterday morning, at the time above stated, Mr. Brock and his men left the factory to go to breakfast, leaving the two boys engaged at the work-board, ramming the sky-rockets. They had scarcely sat down to their meal when they, as well as the inhabitants around them for some distance, heard a sort of rumbling noise as if of some distant thunder, and the next moment a tremendous and deafening explosion followed, and the air was illumined with lights of various descriptions, and accompanied by continued reports. The concussion thus occasioned was so great that the inmates in the different houses were shaken from their seats, many of whom were sitting at their breakfast, and the tables and tea-things were upset and broken to pieces. The window frames were all forced out, and the brickbats and materials were flying about in every direction. The roofs of Mr. Brock's manufactory, and the factory of Mr. M'Devitt adjoining, were blown to a considerable height, and the falling materials did considerable mischief. After the agitation was somewhat subsided, an inquiry into the cause of the accident took place, when it appeared from the statement of the two boys (who were blown a considerable height and were much injured) that they were at work, ramming the rockets, when the ramrod struck against the funnel, and the friction

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caused a spark, which flew into the bowl of gunpowder that stood near them ; this soon exploded, and ran like a train to all the other fireworks in the factory, and at length communicated to the magazines, which caused the disaster. Mr. Brock, however, declares that it could not have arisen in that way, as the nipple of the funnel was copper, therefore a friction would not cause a spark. One poor woman, sister to the beadle, who lives next door to Mr. Brock, was so dreadfully injured by the broken glass that she lies in the London Hospital without hopes of recovery. Ten houses were seriously damaged, and over sixty had their windows broken from top to bottom."

It will be seen from the foregoing that Brock was in advance of his time as regards precautions against explosions, which, however, in this case proved to some extent ineffective.

An accident took place in 1838 at the premises of Cockerill, in Paradise Row, Lower Road, Islington. Three persons were killed, and the proprietor was so severely hurt in an attempt to rescue his family that he died later.

The following year an accident took place at 6 Edward Street, Bethnal Green, in which three persons were injured. The explosion was caused by a spark from the fire falling on a quantity of loose powder lying on the table, the flash from which was communicated to a barrel of powder near. The report continues : " The most miserable negligence was displayed by the persons engaged in the fabrication of the fireworks, as just previous to the accident one of the individuals was making a squib by the fire with a lighted pipe in his mouth." The pyrotechnist's name is not recorded.

An explosion took place in 1841 at 6 Hatfield Place, Westminster Road, Lambeth, at the works of Drewett. Considerable damage was done, but fortunately no one was injured.

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In 1857 Darby's factory at 98 Regent Street, Lambeth Walk, was destroyed. The upper part of the house was used as bedrooms, with the stock below; the whole of the premises and stock were destroyed, the occupants of the bedrooms, who were cut off, being rescued by the aid of ladders. On this occasion the gunpowder appears to have been stored in a magazine away from the house. The report adds that the same premises had suffered in a similar manner on one or two previous occasions, and subsequently, in November, 1873, a disastrous explosion at the same premises resulted in the loss of no fewer than eight lives. In 1858 a serious explosion took place at Madame Cotton's factory in the Westminster Bridge Road.

The above-mentioned accidents do not comprise anything like a complete list, but tend to show the lines on which the manufacture of fireworks was conducted during the period covered.

The frequency of such occurrences and the danger entailed to third parties pointed to the necessity of action of some kind. The old Act might have been put into force, but by so doing the industry would be stamped out, an industry which found employment for a large number of workpeople, and besides giving amusement and entertainment to many, provided signal lights and rockets, the demand for which was steadily increasing.

There were at this time a considerable number of firework makers in London, particularly in the east and south of the Thames. Much of the work was given out to the workpeople's families to make up in their own homes. Workmen now living can remember, as children, seeing crackers, squibs, and other small goods being manufactured in bed and living-rooms of tenement houses in crowded districts, with open fires in the grates and several pounds of powder in a corner of the room.



THE EXPLOSION AT MADAME COTON'S FIREWORK FACTORY, WESTMINSTER ROAD.

From "The Illustrated London News," 1858.

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The materials were either given out at the factory and a piece-work rate paid for making up, or the workers bought their own materials at the local shops, which in these districts kept what was required, and sold them to the factory on completion. It was then a common practice for a maker who had completed a "frame" of quickmatch to take it round to the local bakehouse to be dried and called for in the morning.

Considered from the point of view of modern practice, the wonder is that there were not more accidents than actually took place.

The Gunpowder Act of 1860 was an attempt to place the manufacture and storage of explosives generally on a more satisfactory footing. It laid down regulations to be "observed with regard to the manufacture of loaded percussion caps, and the manufacture and keeping of ammunition, fireworks, fulminate of mercury, and any other preparation or composition of an explosive nature"; and makes it lawful for Justices of the Peace in Quarter Sessions to license places for the manufacture and storage of such articles, and to grant licenses to persons to sell fireworks.

It also provided for the installation of lightning conductors in explosive magazines.

This Act, although far from perfect, was a step in the right direction; it had the effect of bringing some makers out from the back streets of crowded districts, to construct properly arranged factories, or at any rate, factories planned with some regard to their use.

Four years after the passing of the Act, public attention was sharply drawn to the matter by an explosion on an unprecedented scale at Erith, where several of the gunpowder manufacturers had magazines. Enormous damage was done, and many lives lost, over an area ten miles in radius. Lieutenant-Colonel Boxer, R.A., Superintendent of the Royal

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Laboratory, Woolwich, in his report on this explosion, draws attention to the need for a system of inspection of explosive establishments, with the result that he was himself authorised to make such inspection.

Lieutenant-Colonel Boxer was succeeded in 1870 by Captain (afterwards Colonel) Sir V. D. Majendie, K.C.B., who recommended the appointment of permanent Explosives Inspectors.

The late C. T. Brock, who commenced the long run of Crystal Palace displays in 1866, found his works insufficient for the large supply of material required for such displays, and commenced the construction of a factory on new lines at Nunhead. It was here in 1872 that the Royal Commission witnessed a series of experiments, the programme of which is here reproduced.

It was upon the results of these experiments that the provisions of the Explosives Act of 1875, in so far as they relate to fireworks, are based.

This Act is still in force, and is unlikely to be superseded for many years to come. There can have been few Acts which have, since their inception, proved so satisfactory to the industry controlled by them, either in the results achieved, or in the manner of their administration.

The Explosives Acts of 1860 and 1875 took the then proscribed art of pyrotechny from back streets and crowded districts, rehoused it in properly designed and conducted factories in rural or suburban districts, making it as healthy and safe an occupation as almost any in the country.

EXPERIMENTS WITH FIREWORKS AT NUNHEAD,

(In a Field near Messrs. C. T. BROCK & Co.'s Firework Manufactory,)

On THURSDAY, April 4th, 1872.

THE OBJECTS OF THE EXPERIMENTS ARE —

1. To determine if the distance between Firework Sheds, as at present laid down by law, viz. 20 yards, is amply sufficient to prevent an explosion in one shed communicating to other sheds situated at the statutory distance.
2. To determine the liability of Fireworks to ignite by concussion or friction.
3. To determine the liability of Fireworks to explode *en masse* if from any cause they should be accidentally ignited.
4. In the event of Fireworks exhibiting a liability to explode, to determine the area of destructive effect of such explosion.
5. To determine, with reference to the conclusions which may be arrived at as to points 3 and 4, the degree of danger which attends the transport of Fireworks by rail, barge or other public conveyance.
6. To determine at what distance from dwelling houses stores of Fireworks may be safely established.

PROGRAMME OF EXPERIMENTS.

1. Explode 30 lbs. of loose Firework Composition in a Shed, another Shed being 10 yards distant. Screen between.
2. Explode 30 lbs. of Composition in Fireworks in a Shed, another Shed being 10 yards distant. Screen between.
3. Ignite a Box of $\frac{1}{4}$ cwt. of mixed Ordinary Fireworks in open air
4. Ditto ditto ditto in contact with another Box of ditto.
5. Place a Box of $\frac{1}{4}$ cwt. of ditto in a bonfire.
6. No. 3 repeated, with mixed Fireworks bought over the Counter.
7. No. 4 ditto ditto.
8. No. 5 ditto ditto.
9. Hammer various sorts of Fireworks—Wood on Wood.
10. Ditto ditto Wood on Iron.
11. Ditto ditto Iron on Iron
12. Run a Railway Truck over some of the different sorts.
13. Repeat such of above as may seem necessary with "Parlour Fireworks."

V. D. MAJENDIE, CAPTAIN R. A.,

H.M.'s Inspector of Gunpowder Works, &c.

CHAPTER VIII

MODERN FIREWORK MANUFACTURE

FIREWORKS are now manufactured under the Explosives Act of 1875 and Orders in Council No. 2 and No. 4 under that Act.

Order in Council No. 4 deals with small Firework Factories, the total contents of which, either finished or in course of construction, do not exceed 500 lbs. This class of factory presents little of interest for consideration ; and is governed by practically the same rules as are the larger establishments of the kind, with such modifications as are justified by the small quantity of explosive material involved.

Order in Council No. 2 sets out the general rules to be observed in factories licensed under the Act, the leading points of which are as follows :

The absence of iron or steel in any workshop, carriage, or boat ; cleanliness and absence of grit ; care as to material liable to spontaneous ignition ; provision of lightning conductors on magazines ; tools and implements to be of soft metal ; working clothes without pockets ; shoes without nails ; searching or means to prevent the introduction of matches or dangerous substances into the works ; materials and finished work to be removed from working buildings and not allowed to accumulate when any particular process is completed ; no person under sixteen years to be employed or enter any danger building. Every building to be provided with a set of these rules, and a statement of the quantities of explosives and ingredients, and the work to be carried on in it as allowed by the license.

The modern factory is generally situated in a rural district

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on account of the fact that it is more easy to observe the statutory distances from protected works. Protected works referred to in the Act include other workshops and magazines in the factory, and also dwelling-houses, factories, institutions, railways, highways, and various undertakings and buildings, the distances to be observed varying with the nature of the protected work from public highways to palaces or houses of residence of the King, his heirs and successors. In some cases, as with private dwelling-houses, the distance to be observed is about half, if the consent of the occupier to the erection of the factory building or magazine is obtained.

Firework factories, in fact all explosive factories, are constructed on the principle of limiting the scope and effect of any explosion that may take place to the smallest possible quantity of material and to the smallest possible risk to human life.

The working buildings are constructed with a door at either end to facilitate escape in case of danger; the quantity of chemicals and of partially or wholly finished fireworks is strictly limited, as is the number of persons employed in the building. This number varies with the nature of the operation being carried out, from one in the case of the most hazardous to six in some cases.

The working buildings are of light construction; the form most in use is a timber framing lined with matched boarding and covered externally with corrugated iron. No iron fittings are used, or iron nails left exposed in the interior. The floor is covered with linoleum, which is secured by copper tacks.

The distance separating working buildings is, generally speaking, twenty-five yards, or if a suitable screen is placed between two such buildings, this distance may be reduced to twelve yards.

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The workpeople are provided with non-inflammable outer garments, no pockets are allowed, and suitable overshoes of sewn leather or indiarubber are provided.

All tools are of soft metal, such as brass or copper, or of wood.

The regulations refer, of course, only to those buildings in which explosive work is carried on, that is to say, buildings in the danger area as distinct from the non-danger area.

The buildings in the danger area are working buildings, drying-rooms, expense and factory magazines. Expense magazines are those which are licensed for a comparatively small quantity of explosives, and from which explosive material is drawn as the work of the factory demands, or into which is put partially or wholly finished work either awaiting completion or transference to the main or factory magazines.

The non-danger area includes stores for chemicals, paper, and other material, also case rolling and drying sheds, saw-mill, wood-working and paper-cutting shops, offices, and similar buildings.

The manufacture of fireworks begins with the making of the case or container, which, with the exception of shells and Jacks-in-the-box, are cylindrical in form.

What are known as "small goods" are "dry-rolled," that is, the outer edge of the paper only is pasted. They are then rolled up on a metal former on a slate slab.

The larger cases, such as rockets, gerbs, and Roman candles, have the paper pasted all over, which is rolled up on the former and consolidated by repeated rolling between the slate slab and a board provided with a handle.

There are two methods of introducing the composition into the cases—filling and charging.

Filling is used where the composition does not have to be consolidated, and is done with a wire and funnel, or as it was

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formerly called, a "tun dish." The funnel has its outlet of such a size as to fit the case to be filled, the wire or rod is somewhat smaller than this outlet, and is provided at the upper end with a knob for the hand. The end of the funnel, which is filled with composition, is inserted in the upright case. The wire is then drawn up, thus freeing a small quantity of the composition which runs down into the case, the lowering of the wire pushing it into position. In order to render the downward movement more effective, the wire is often notched, but it is doubtful if this actually increases the efficiency. This action is rapidly repeated until the case is filled.

This method, although simple, is very effective, and in the hands of a practised worker is exceedingly quick.

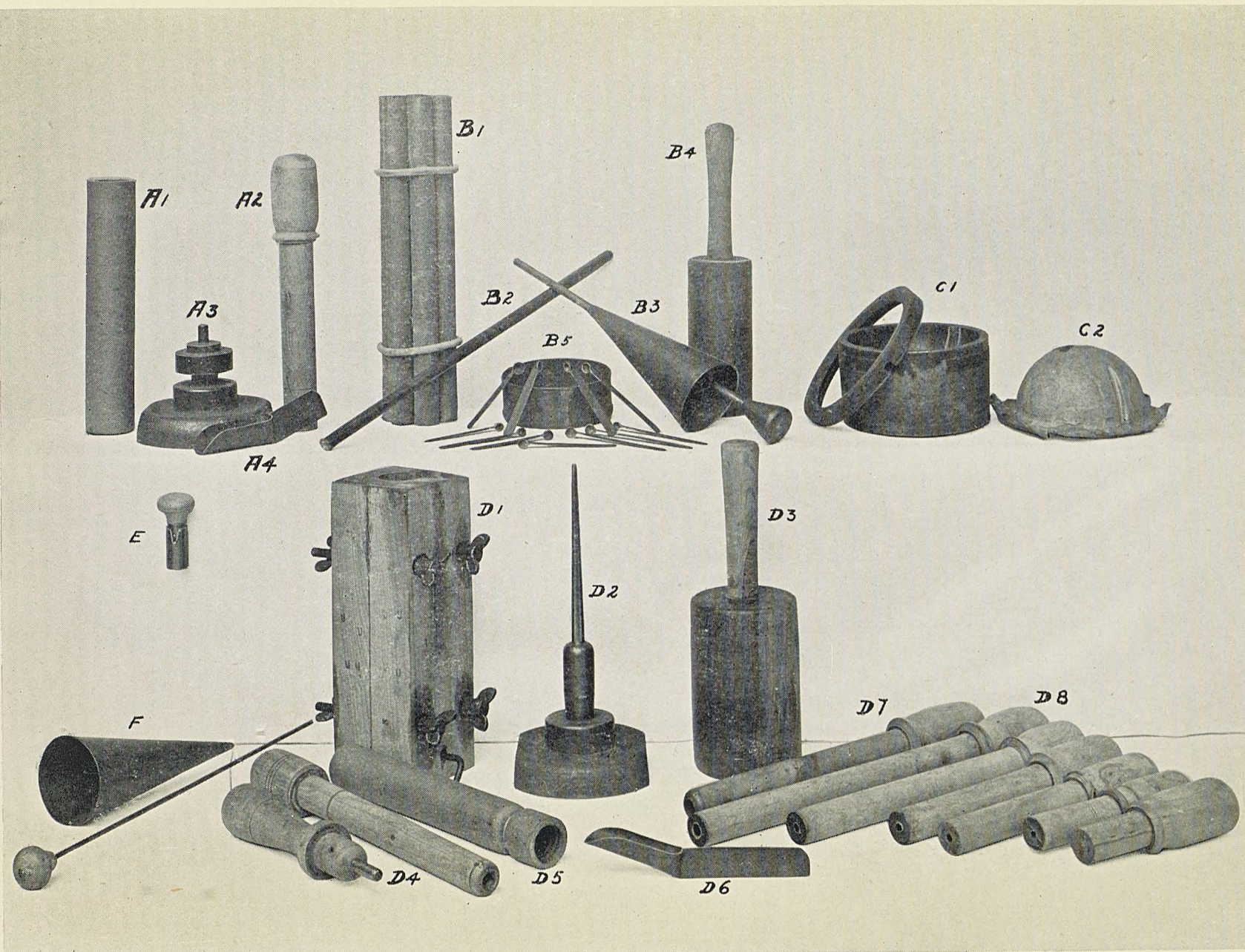
Charging is adopted where the contents have to be solidified in the case. The composition is introduced in small quantities with a scoop of suitable size and consolidated by repeated blows with a wooden mallet on a "drift." The drift is a cylindrical wooden tool of a size to fit the case, and an enlargement at the upper end to receive the blow of the mallet.

The methods of charging the various forms of fireworks will be dealt with later under their separate headings.

The method of charging rockets in use in the sixteenth century are those of to-day, and it is remarkable that no satisfactory alternative to hand charging has yet been devised. Mechanical hammering and hydraulic pressure have both been tried, but so far with limited success.

Stars which are used in Roman candles and as garniture for rockets and shells, are of many kinds and combinations, but with the exception of some which are in effect complete miniature fireworks, they are constructed on one of three methods—they are either "pumped," "pinched" or "charged."

The pump used in the first of these operations consists of



GERB TOOLS

- A1 Case.
- A2 Drift.
- A3 Nipple.
- A4 Scoop.
- B4 Mallet.

ROCKET TOOLS

- D1 Mould.
- D2 Spindle.
- D3 Mallet.
- D4 Choking Tools.
- D5 Choked Case.
- D6 Scoop.
- D7 Setting down Tool.
- D8 Graduated Drifts.

ROMAN CANDLE TOOLS

- B1 Bundle of Cases ready for filling.
- B2 Drift.
- B3 Topping Funnel and Drift.
- B5 Powder Bowl and graduated Scoops.

- C1 Shell Mould.
- C2 Half Shell Case as taken from mould.
- E Star Pump.
- F Funnel and Wire.

Modern Firework Tools.

MODERN FIREWORK MANUFACTURE

a short metal tube, which fits exactly a short metal plunger provided with a knob for the hand, and a small metal stud at the side. The tube has a slot cut partially down the side to receive this stud.

The method of using the pump is as follows :—The plunger is drawn up so that the stud rests on the top of the tube. The pump is pressed into a heap of prepared composition, which action has the effect of compressing the composition in the tube. The plunger is then turned so that the stud engages with the slot, and pushed down, forcing the star out of the tube. The composition is prepared for pumping by being damped with methylated spirit or some other suitable solvent, and after making, the stars are dried in specially constructed buildings.

Pinched stars are made by pinching the damped composition into a short paper case, through which a short length of match is first passed.

Charged stars have generally a clay or cardboard bottom to the case, and are usually matched. This form is generally used for Government signal rockets, as the composition being only at one end of the case, the time of burning is extended.

The mixing of compositions requires great care and thoroughness. Care both on account of the necessity of exact adherence to the formula, and to preclude the presence of any foreign body or chemical which, apart from any effect it might have on the successful functioning of the fireworks for which it happens to be used, might render it most dangerous in manipulation.

Generally working buildings are licensed for mixing compositions, but it is usual to set certain sheds apart for this purpose, especially if the chemicals used are of a dusty nature, that is, very finely divided, in which case the atmosphere becomes highly charged and dangerous.

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Chlorate of potash, from the introduction of which into pyrotechny modern effects and colours may be said to date, has at the same time been responsible for many accidents. As will be seen in the later chapters on firework compositions, for many years chlorate of potash and sulphur were used freely in the same mixtures, and many as were the accidents caused by so doing, yet it is incredible that they were not far more numerous.

Most makers were well aware of the dangerous nature of this admixture, but persisted in using it, as the colours so obtained were at that time unapproached by other means; naturally no manufacturer wished to be alone in the discontinuance of some of the most striking effects at the time available, or to give competition the consequent advantage.

In August, 1893, a man was fatally burned whilst simply emptying a small quantity of crimson stars from one tray to another; the slight friction so caused was sufficient to ignite the stars and thus fire the whole contents of the building. This unfortunate accident took place at the works of C. T. Brock and Co., then at South Norwood, and seems even more unfortunate when one learns that with the exception of this particular crimson, they had practically eliminated chlorate and sulphur colours.

The following year, by Order in Council No. 15, the admixture of chlorate of potash and sulphur was made illegal.

Previous to this accident, during the same year and in the same works, a serious accident involving the death of one workman and the injury of another, was caused by a barrel of chlorate of potash being delivered and marked nitrate of potash (saltpetre). Its use in a composition containing sulphide of arsenic (orpiment) produced a mixture approximately to that used in some fog signals and designed to fire by percussion. The natural effect was the serious explosion that followed.

MODERN FIREWORK MANUFACTURE

The late Sir Vivian D. Majendie, K.C.B., the then Chief Inspector of Explosives, records in his report that "Messrs. Brock are extremely careful to keep chlorate and non-chlorate mixing departments, and even ingredients in separate buildings and under separate control," and while he considered that "some measure of blame is attributable to them in respect of the defects of their system which rendered possible the presence of a cask of chlorate of potash as "saltpetre" in the saltpetre shed," he adds : "It is only fair and proper that I should say that our experience of the manner in which Messrs. Brock conduct their large business generally is extremely satisfactory. This factory is in many respects a model ; they have always shown themselves ready to discuss with us and adopt any suggestion tending to increase the safety of the workpeople."

These indications, if such were needed apart from the official prohibition of the use of these two ingredients together, convinced Mr. Arthur Brock that even greater care was necessary in dealing with them. With this object in view, when the works were removed to Sutton, Surrey, the two factories at South Norwood and Harold Wood, Essex, being inadequate to deal with the business, the plan of the new factory was arranged so as entirely to separate that portion of the factory using chlorate of potash from the portion using sulphur. A road running up the factory from the entrance gate divides it into what are virtually two factories, known as the Colour and Bright Sides.

These works, which are easily the largest of the kind in the world, cover an area of nearly 200 acres. They include about 60 magazines, expense magazines, and drying rooms, with a total storage capacity of 1,300,000 lbs. of fireworks and 5 tons of gunpowder ; 120 explosive working buildings (mostly double), besides numerous stores, non-explosive working

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buildings, saw-mills, and wood-working shops. The buildings are connected by over four miles of tram-lines. The average number of employees is 150 men and 200 women. During the late war this number was increased to over 2,000 on the manufacture of munitions.

CHAPTER IX

FIREWORK ACCIDENTS

THE record of firework accidents until the date of the Explosives Act, 1875, is very meagre, not in subject matter, as reference to Chapter VI will show, for the history of the industry up to that time appears to have been one catalogue of accidents; the only cause for wonder when one considers the conditions then prevailing is that there were not more. But in detail, the only records are more or less sensational reports of the event, and such explanation of the cause as the reporter could pick up from some bystander.

In some cases where the workers were not killed the explanation was found to be simple; as for instance, the accident at Mortram's works in 1821. Here a boy who was making stars in a room with several other workers and other composition present, put some of his work to dry before the open fire, and as if this was not a sufficiently reckless proceeding, lit one on the hob, with the consequences that were to be expected.

In most cases, however, the cause seems to have been obscure, and little or no trouble appears to have been taken to discover the cause with a view to prevention of a repetition.

Since the Explosives Act careful record is kept of all accidents; the scene of the accident is inspected, and a report printed, setting out the cause, so far as can be ascertained.

Until the introduction of chlorate of potash about 1830, if even reasonable care had been used the chances of spontaneous ignition were very small, and it is reasonable to suppose that such accidents as did take place were in the majority due to such incidents as the above.

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After that date, however, it is not too much to say that quite as large a proportion of accidents were due to the admixture of chlorate of potash and sulphur.

We are, of course, now speaking of accidents during manufacture, although to the same cause may be attributed many of the numerous cases of bursting mortars during displays which were so frequent until the prohibition of this mixture in 1894 by Order in Council 15.

Dr. Browne, of Hull, a consulting chemist, published in 1884 a book entitled, "Firework Accidents, their cause and prevention," in which he divides accidents into three classes : mechanical, chemical (spontaneous combustion), and mechano-chemical.

Such a classification seems to the writer misleading, as all accidents must of necessity be chemical ; that is to say, for combustion chemical action must take place ; and with the exception of cases where ignition has taken place quite spontaneously, that is where the composition has ignited when lying perfectly undisturbed, all must be considered mechanical.

Almost any composition used in pyrotechny, however stable, can be ignited by a violent blow between two hard surfaces, but some compositions are so unstable as to be ignited by very slight friction.

It is therefore a question of degree, or whether the mechanical factor is most to blame or the chemical. A better classification would be :

I. Ignition caused by violence, friction or heat.

II. Accidents caused by the state, condition or quality of the composition or ingredients.

If the accident be included in the class which gives the fundamental cause of the accident, it will be found that the

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greatest number fall in Class II, even though they may at first glance appear to belong to the first class.

Class I includes accidents caused by the accidental presence of fire and accidents caused by necessarily more or less violent action in manufacture, that is to say, in charging.

Ignition during charging may be caused in two ways, either by a blow on composition between the charging tool or drift and the spindle or other hard surface, or by heat generated by repeated blows on the consolidated composition.

In this class also should be put accidents, of which there are many, caused by playing or scuffling by the workpeople, the absence of safety overshoes, the presence of grit or iron or steel implements, in fact those caused by misconduct or negligence on the part of the workers, also the rare occasions where lightning has been the cause.

Accidents caused by slight friction have to a great extent ceased to exist owing to the elimination of chlorate and sulphur compositions. Where accidents arise owing to instability of the composition, they most frequently at the present time fall within Class II, as the instability of the composition is generally due to the presence of some impurity in one or more of the ingredients.

Another source of accident of this class is the use of violence in emergency with a composition which, although not sufficiently stable for heavy charging, is quite safe for careful manipulation; as for instance, where force is exerted to clear a funnel which has become blocked with composition, or some similar action.

As regards the part played by heat in accidents of this class, a study of the records clearly indicates how great is the influence of weather. By far the greatest number of accidents take place in the summer months; hot weather and a heavy

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atmosphere are the most likely conditions to produce trouble for the pyrotechnist, although whether the primary cause is heat or owing to an electrical condition of the atmosphere it is difficult to say, probably it is the two conditions in conjunction. Sulphur and shellac, two very important ingredients in the art, are both capable of holding an electric charge, and it seems not unlikely that they may be so charged in an electric atmosphere during the process of mixing.

Accidents in Class II are generally less easily explained than those in the former class and have occurred in many forms. As has been said, during the period (about sixty-five years) from the introduction of chlorate of potash to the Order in Council forbidding its use with sulphur, numerous accidents occurred ; spontaneous ignition, both whilst drying during manufacture and even during mixing, ignition from very slight friction, and for a time a frequent occurrence the detonation of the contents of shell by the lifting charge. During the period of seventeen years between the date of the Explosives Act and the prohibition of chlorate sulphur mixture, twenty-eight accidents are recorded, resulting in eleven deaths attributable to the use of such mixtures.

The instability of chlorate sulphur compositions, however, does not appear to be so much due to the presence of these two chemicals themselves, but rather to the presence of impurity in conjunction with them.

Commercial sulphur often contains free sulphurous acid, which acting upon the chlorate produces chlorine tetroxide, which rapidly decomposes and ignites the mass of the composition.

Other acids which produce decomposition of the chlorate are equally likely to produce ignition. Of such cases, examples may be mentioned of acid being present in the paste used for case and box-making, also in gumwater which has been kept

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some time before using, and in starch paste similarly treated. Spontaneous ignition has also been caused by the contact of oil with finely divided carbon such as lampblack or finely divided metals, such as magnesium and aluminium, which are so largely used at the present time.

Another case of this nature is the heating up of cases after charging with gerb composition, two of the ingredients of which are sulphur and iron borings, this heating sometimes being sufficient to cause combustion. The cause of this phenomenon is the combination of the iron with sulphur to form sulphide of iron, this action being accompanied by heat. In fact, it is the same as that producing the experiment known as Lemery's volcano. As far as the knowledge of the writer extends, however, no occurrence of ignition has been definitely traced to this phenomenon, although it seems highly probable that even if ignition of the actual composition has not taken place, cases have occurred where more sensitive compositions have been fired by heat so generated where fireworks have been stored together.

The annual reports of H.M. Inspectors of Explosives published since 1876 form an interesting and instructive summary of accidents in explosive trades, an examination of which throws considerable light on our subject.

One is struck by the frequency with which explosions occur as a result of ignorance, generally on the part of amateur firework makers. In many cases, as where children are concerned, this ignorance is natural, but the want of knowledge and even reasonable care displayed by individuals whose occupation suggests at least some knowledge of the risk is indeed often extraordinary.

Such a case occurred in 1884 in Devonshire, when a local chemist who was illegally manufacturing coloured fire, instructed an assistant to grind in an iron mortar a mixture

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containing chlorate of potash and sulphur. The lad was killed in the resulting explosion.

Even more remarkable was an explosion which took place in a railway carriage in 1893. This was due to the spontaneous ignition of a quantity of chlorate and sulphur coloured fire, which was being carried in an ordinary handbag by a gentleman whose occupation in life was that of professor of chemistry.

An accident presenting considerable interest took place in 1885 at Mitcham. The cause of this occurrence was quite simple. A man was fixing the curved stick which forms the pivot upon which a tourbillion rotates to one of those fire-works. The wire nail used for the purpose penetrated the composition and fired it. The remaining goods in the shed were ignited, and communicated to the neighbouring buildings, one of which was a magazine containing 3,000 lbs. of partially manufactured fireworks, including a number of rockets. These being without sticks and becoming ignited flew in all directions, setting fire to other buildings. The result was that ten buildings and an air drying rack were totally destroyed, and three buildings and three racks partially so.

This would seem a very serious matter as far as monetary damage is concerned, but as regards the chief consideration in accidents of this kind, that is to say damage to human life and limb, the result was almost negligible ; two persons were slightly injured.

This accident, which was the most extensive in any fire-work factory since the Explosives Act came into operation, afforded striking proof of the efficiency of the precautions instituted under that Act.

It is indeed extraordinary that in an explosive factory of considerable size, employing many workpeople, during working

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hours it should be possible to destroy more or less completely seventeen buildings and only slightly injure two persons.

It may be contended that the number of buildings damaged was very high, but it must be remembered that rockets without sticks take a most erratic course in their flight, rendering the effective screening of other buildings most difficult, if not impossible.

However, there is evidence that many rockets were stopped by the screens, and that without their interposition the number of buildings destroyed might have been many times greater.

The other Explosives Act requirements of which the efficiency was demonstrated by this accident, are the dividing of sheds into compartments with a limited number of work-people in each, easy means of escape from working buildings, and the value of unflammable clothing.

It was also shown that a large quantity of fireworks might be burnt in mass without causing a veritable explosion ; as in the case of the magazine containing 3,000 lbs.

Contrasting with this occurrence are the reports of accidents in firework factories both on the Continent and in America.

The same year, at Civita Vecchia, ten persons were killed and twice that number injured in one accident at a firework factory.

Four years later, in Paris, seven girls were killed out of the eighteen employed in one compartment. The material being used was red phosphorus and chlorate. In 1882 fourteen persons were killed and no fewer than seventy injured at Chester, Pennsylvania.

From 1891 to 1894 eight accidents in the United States are reported, resulting in a total of twenty-three deaths and injury to more than fifty persons. In 1894, at New Haven, Con., damage to the extent of 125,000 dollars was done, and at Dallas a considerable part of the city was destroyed.

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These are, of course, not a complete list, but only such cases as are brought to the notice of the English Home Office, but the extent of these clearly illustrates the value of the restrictions in force in this country.

During the same years the total of firework factory accidents in this country was thirteen, in which three persons lost their lives, and in no case was more than one person killed in any one accident. Indeed, in one instance only since 1875 has the number of deaths resulting from any accident exceeded two—on that occasion four deaths resulted.

An interesting type of accident, examples of which have taken place on several occasions, is that in which two compositions, one containing sulphur and the other chlorate of potash, are placed in contact in the paper case of a firework, and produce spontaneous combustion.

In one case a lance containing white and green composition burst into flame on the work bench. This provided an explanation to an explosion at the same factory which had taken place ten days before in a magazine containing between 6,000 and 7,000 lbs. of display fireworks.

An occurrence of a similar nature was observed at Brighton in 1903, when some changing coloured lights which had been removed from a building where a fire had taken place (the fireworks not being involved in any way) ignited some days afterwards.

It is thought that the lights may have been wetted during the fire, and upon drying out some days later the different compositions in contact in the case or cases set up chemical action, which resulted in spontaneous ignition. It was found on examination that a blue containing sulphur was in contact with a green containing chlorate. It may be noted here that mixtures which are damped during manufacture are more liable to spontaneous ignition than those manipulated in a dry state.

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Many accidents and explosions are left unexplained, either because the evidence is destroyed by the resulting fire or by the death of the witness or witnesses, or because of the difficulty often experienced in getting the workpeople to give a full and truthful account of what occurred, fearing to cause trouble for themselves or others concerned.

There can be no doubt that the cause is frequently carelessness or mistakes on the part of workers. In a large number of cases, however, this explanation gives no help and the cause remains obscure. One such may be mentioned :

In 1902 an explosion occurred in a store for non-explosive ingredients, in which were kept the chemicals used in a firework factory. In the building at the time was a workman who appears to have been engaged in sifting chlorate of potash, and the technical manager of the factory who seems to have been weighing out ingredients. There is no doubt that he was a man of very considerable experience, and from his responsible position unlikely either to take risks or be guilty of carelessness.

An explosion occurred in the building, killing both occupants, and of so violent a nature as to sever the foot of the manager and to project one of the sheets of corrugated iron with which the roof was covered a distance of thirty yards.

No explanation of this occurrence was arrived at other than that in some way some of the chemicals must have become mixed to form a sensitive and violent explosive ; so much is obvious, but how the chemicals became so mixed remains a mystery, as no mixing was actually done in the building. The ignition of such a mixture is less obscure as magazine boots were not necessary in the building owing to the non-hazardous nature of the work carried on there, and sufficient friction would be produced to fire even a fairly sensitive mixture between a nailed boot sole and a wood floor.

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An occurrence of considerable interest in this direction took place in a warehouse at Manchester in 1908. In the building were stored several tons of chemicals, among which were twelve tons of chlorate of potash and thirty-two of chlorate of soda.

A workman stepping down from a barrel struck fire, and saw a flame, which he tried to extinguish by rubbing with his foot. This, however, had the opposite effect. He then tried a bucket of water, which failed to put it out ; he left the building and heard an explosion, followed by a second and a third, all apparently of a violent nature, all three being heard nearly ten miles away, and glass broken throughout a considerable area round the warehouse.

The cause appears to have been as follows : During the conveyance of the chlorate into the building leakings took place, and a certain quantity remained on the floor, this mixing with dust and other organic matter would prove a highly sensitive composition. This was ignited by the man's foot and rapidly spread, probably a deposit which had accumulated under the floor became involved. The woodwork of the building and the wooden barrels then became ignited. The rapid decomposition of the chlorate caused by the heat liberated large quantities of free oxygen, which united with carbon in the smoke to form gas, which exploded upon reaching the correct proportion for so doing.

The writer has chiefly confined himself to accidents in firework factories ; those occurring during the illegal manufacture of fireworks in premises unlicensed for the purpose present no further interest, and are generally caused by ignorance on the part of the participant of the often extremely dangerous nature of the material he is handling. To take an example :

Two boys were engaged in grinding in a mortar a " small

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quantity " of chlorate of potash and sugar. An explosion resulted which blew out the entire window frames of the room, destroyed the partition between the room and the passage, considerably damaged the other wall, and projected the pestle into the ceiling, where it remained embedded.

Accidents at displays are now happily rare; the most fruitful cause of such happenings was the detonation of shell in the mortar, that is, the detonation of the contents or " garniture " by the explosion of the propellant charge.

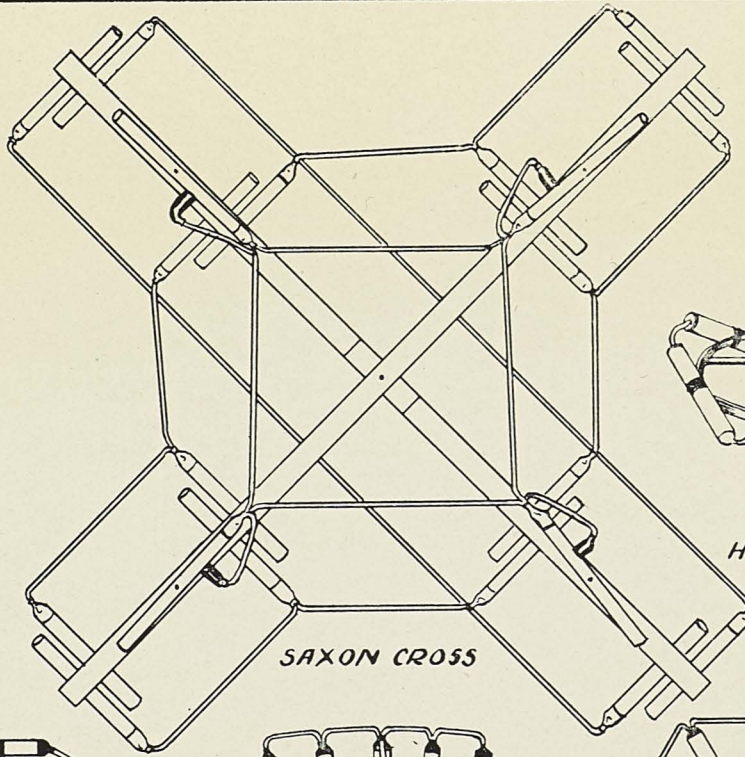
The elimination of chlorate-sulphur composition has reduced the chances of this to a minimum, and the compulsory burying of mortars up to the muzzle has practically eliminated the danger to either firers or spectators.

Apart from slight injuries caused by falling rocket sticks and mishaps of a similar nature, accidents to the public at firework displays are things of the past.

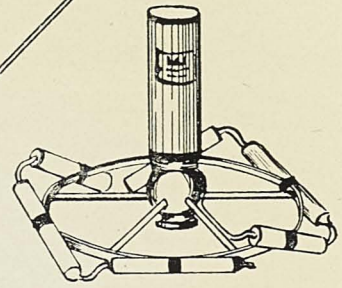
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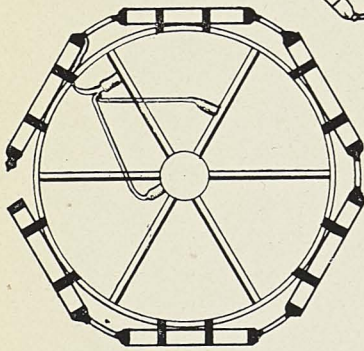
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THE TAILORS



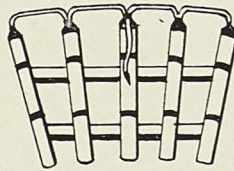
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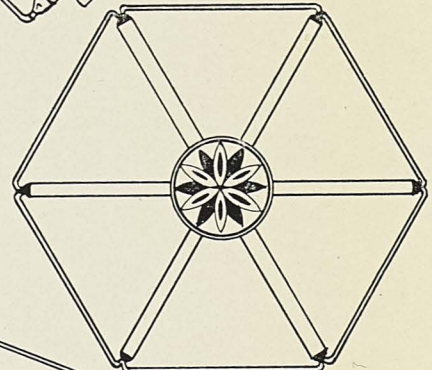
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& MINE



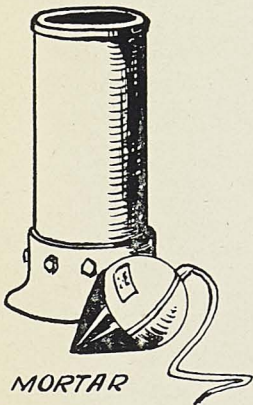
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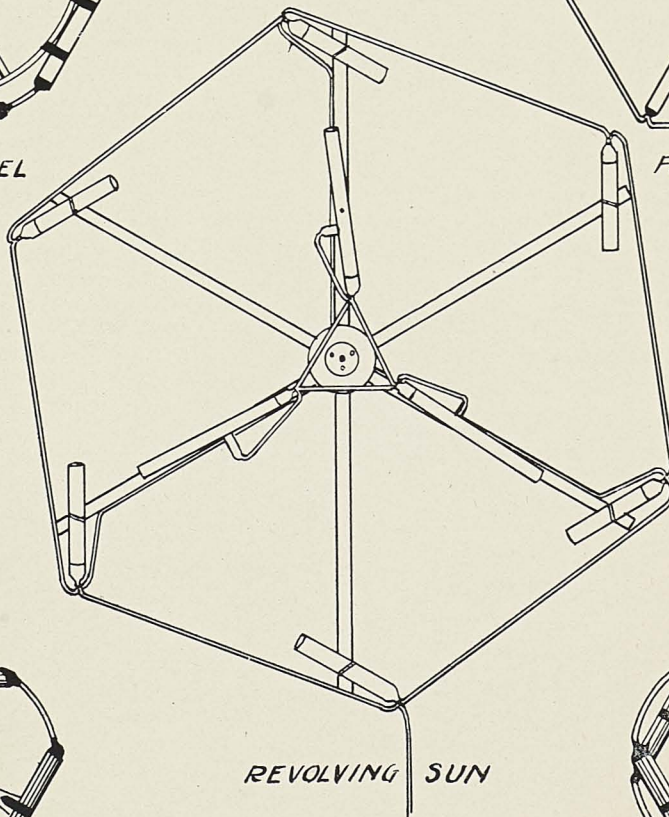
BOQUET OF ROMAN CANDLES.



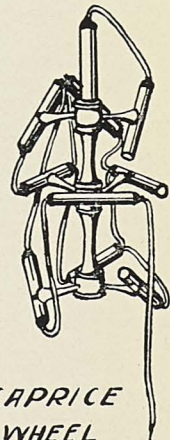
FIXED SUN



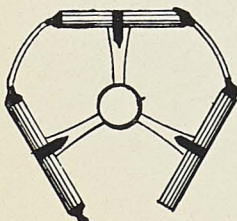
MORTAR
& SHELL



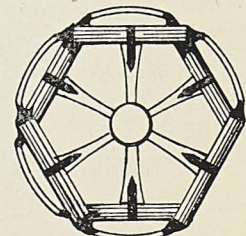
REVOLVING SUN



CAPRICE
WHEEL



SINGLE TRIANGLE WHEEL



DOUBLE TRIANGLE WHEEL

CHAPTER I

SIMPLE FIREWORKS—ROCKET CLASS

IN the preceding chapters we have been dealing with displays of fireworks, that is to say; fireworks in the mass. We will now turn our attention to the firework units composing those displays, and endeavour to trace their gradual evolution from the crude originals.

Fireworks may be divided into two classes, simple and compound. The first of these include fireworks which are a complete item in themselves, as the rocket, shell, or Roman candle; also the units which, fitted on a framework, go to compose the set pieces and devices of a display, and the small shop goods not used in displays. We will consider this class first.

The two oldest forms of fireworks known are undoubtedly the cracker and the rocket. As we have already noted, both of these—or at least primitive forms—are mentioned by Marcus Graecus, Albertus, and Roger Bacon. The description by the former is sufficiently clear to leave no doubt in our minds that he is describing a rocket; although the description of a cracker is not so explicit as to enable us to say that he is actually describing a jumping cracker, yet his mention of folding and tying would certainly give colour to that belief. In fact, some writers have endeavoured to find a connection between the words “Graecus” and “Cracker.”

Greene, in “Orlando Furioso” (1599), uses the words, “Yes, yes, with squibs and crackers brauly.” John Bate, in his book previously mentioned, under the somewhat misleading heading, “How to make Crackers,” says: “It is well knowne that every boy can make these, therefore I think it

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will be but labour lost, to bestow time to describe their making."

He also describes a kind of kite which he designates a "Fire Drake," to the tail of which he fastens "divers crackers" which are shown in the illustration to be exactly like the jumping crackers of the present day. Babington illustrates a cracker fixed to the top of a rocket.

Pepys makes the following entry in his diary for November 5th, 1661: "Seeing the boys in the streets flying their crackers."

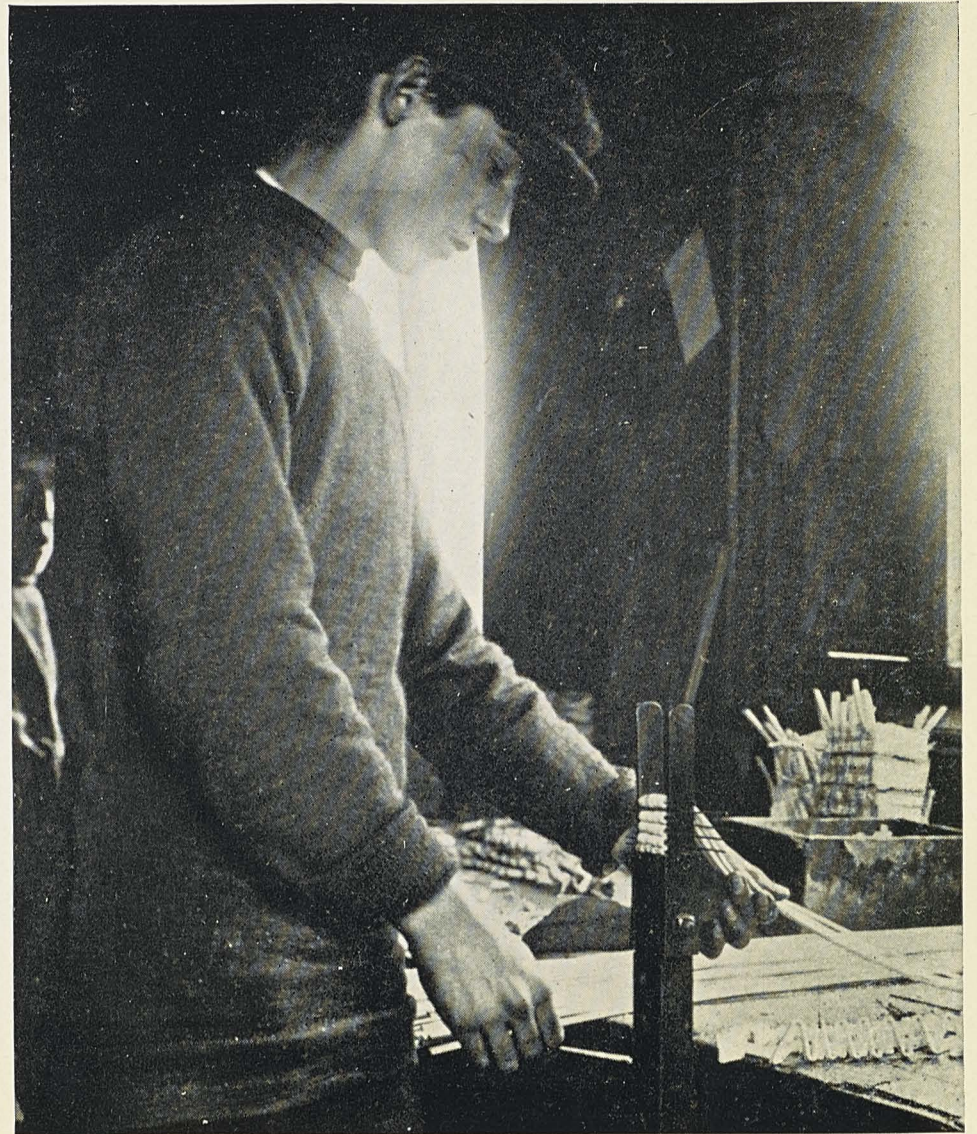
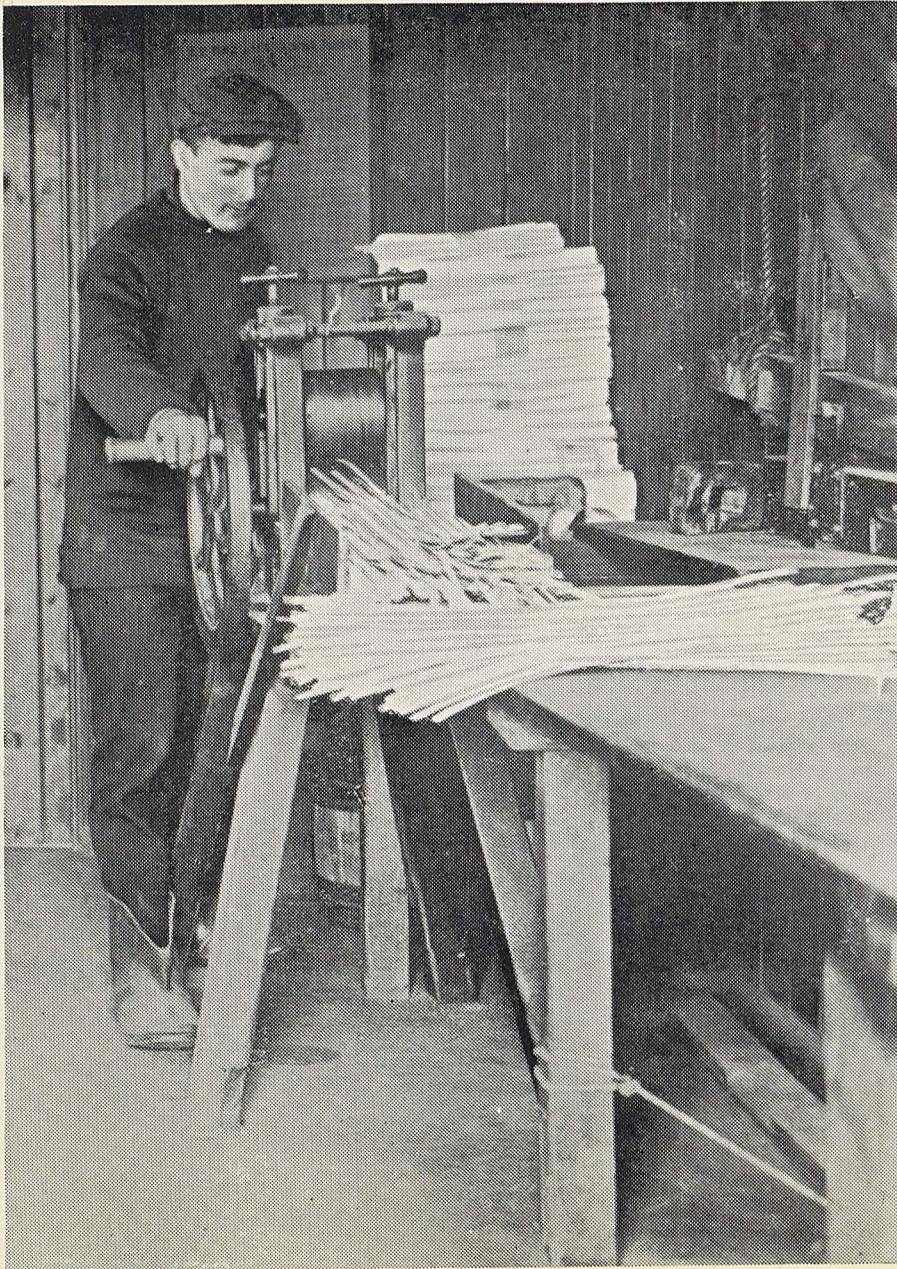
The only practical difference between the cracker of 1635 and that of to-day is in the difference of methods of manufacture, the early practice being to fold the gunpowder in the paper, the modern, to roll a paper case and fill the powder in through a funnel, afterwards flattening it through a roller mill.

Curiously enough, although the cracker has been in use for centuries in England, there appears to be no early reference to it on the Continent, the word "petard" meaning a cracker in French, but more often being applied to a firework with a single report, such as a maroon or cannon. The *Dictionnaire National* of 1852, however, describes the true cracker as one of the meanings of "petard."

The rocket is equal to the cracker in its claim to antiquity, and it is extraordinary that these two fireworks should have changed so little in form and composition.

John Babington gives illustrations of rocket-charging tools and describes the manufacture of rockets, which are approximately those of the present day. It is only in the proportion of the ingredients that there is any considerable alteration.

The word "rocket" appears to be Italian in origin, and to be based on the similarity in appearance of a rocket on its stick to the round piece of wood used in the Middle Ages to cover the point of a lance in mimic combat, and known as a



Cracker Making

SIMPLE FIREWORKS—ROCKET CLASS

“rockette,” from “rocca,” the Italian word for a bobbin, a diminutive of distaff.

As a rocket is the most important unit in the art of pyrotechny, a description of its manufacture will assist in the consideration of a large number of other fireworks which are either modifications of or based upon the underlying principles of the rocket, as well as the several principles governing all fireworks.

The ingredients of rocket composition are those of gunpowder in approximately similar proportions, but the resultant composition is not gunpowder, the reason being that the ingredients are less intimately mixed, with the result that the combustion is spread over a longer interval of time. Instead of the whole mass deflagrating instantly, only the exposed surface is consumed. It is the recoil produced by the rush of gases, and partially consumed matter, from the violently burning composition which projects the rocket forward. The obvious form for the case containing the composition is cylindrical, both on account of ease of construction and of charging. In order to get the greatest possible reaction from the burning composition, the case of the rocket is constricted or choked, so that the fire may issue as it were in the form of a jet. This choke has one obvious disadvantage, it reduces the surface of composition to the area of the opening, thus restricting the initial burning surface at the time when the maximum of effort is required to force the rocket into motion. This defect is overcome by having a tapering hole up almost the entire length of the composition, thus giving a large burning surface with a consequent discharge of gas through a small orifice and a resultant powerful jet of fire and gas.

The rocket case is of stout paper rolled on a former consolidated by rolling under a board. The choke is formed by inserting into the bore of the rocket two wooden tools with

PYROTECHNICS

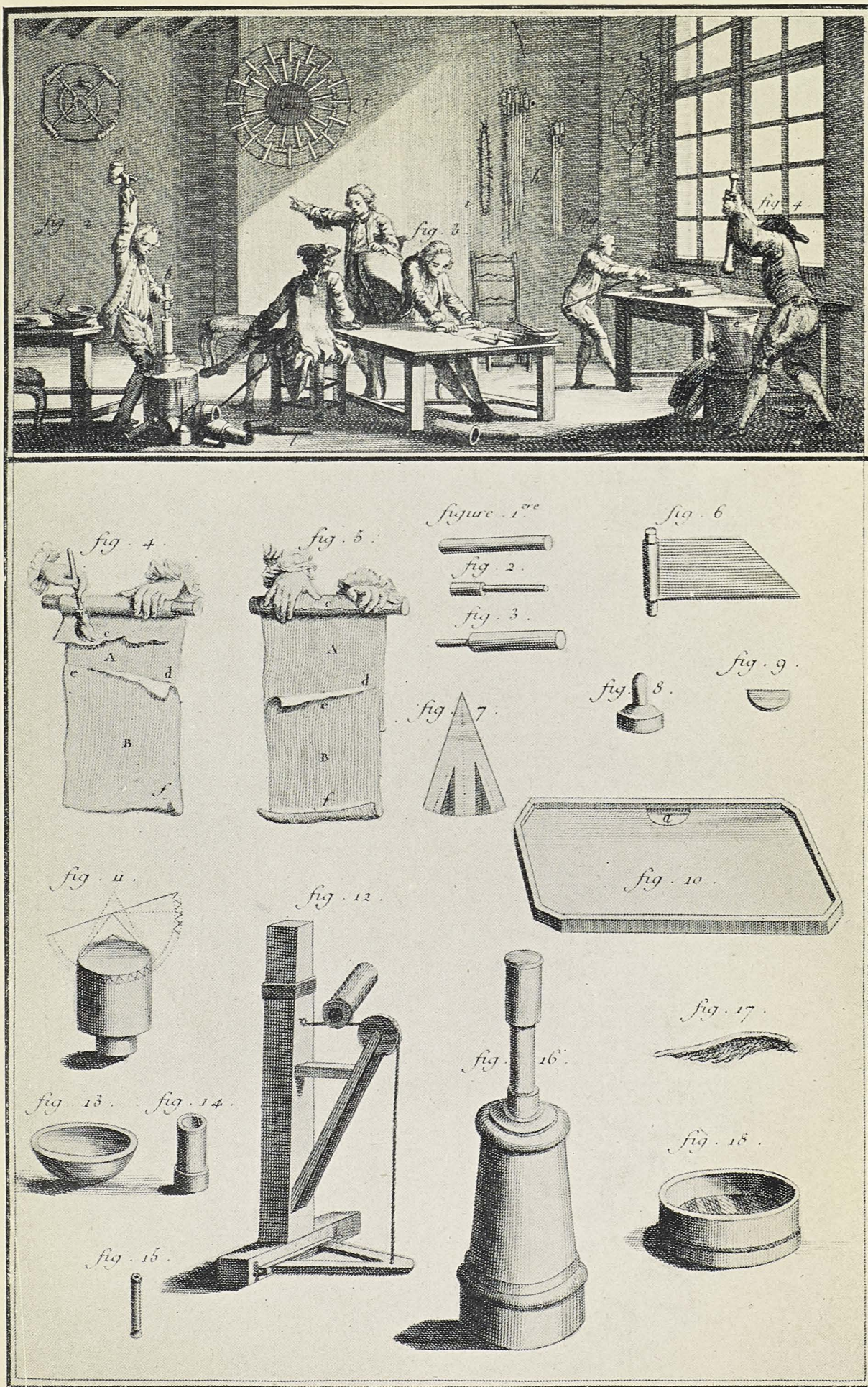
rounded ends, the shorter tool having a peg projecting which is equal in diameter to the bore of the choke. The tools are of such length that when they are inserted the peg takes up the position where the choke is to be formed. The case is then constricted at this point by a strong pressure with a stout cord wound round the case and soaped to allow it to slip round easily.

The case is then dried and charged by placing on a "spindle," which is a strong gun-metal base with a nipple fitting into the vent of the rocket and having a tapering spindle which fits tightly in the choke and projects up into the bore of the rocket. The composition is poured in in small quantities measured in a scoop, each scoopful being consolidated by blows with a wooden mallet or a wooden "drift" hollowed to take the spindle. Before the first scoop of composition is introduced, the rocket is "set down," that is, several blows are given on the drift to consolidate the paper at the choke and give it accurate shape. Next, a scoop of ground dry clay is poured in and charged firm as a protection to the paper of the choke. The charging is then proceeded with as detailed above. Varying drifts are used in order that the hole may approximately correspond with the diameter of the tapering spindle as the composition rises in the case.

A short portion of the case above the spindle is charged solid; this is referred to as the "heading," and is usually about one and a half times the bore in depth.

Large rockets are charged in a mould which fits tightly round the outside of the case and prevents the case being split under the pressure of the blows whilst being charged.

In early times these moulds were used for all sizes and were of cast metal, and it is from them that the classification of the sizes is derived. Rockets are designated by the weight of a ball of lead which fits the bore of the corresponding mould.



Rocket Manufacture, from Frézier's "Feu d'Artifice," 1747,

SIMPLE FIREWORKS—ROCKET CLASS

Thus we have rockets varying in size from $\frac{1}{2}$ oz. to 6 lbs. and over, war rockets being made up to 9 and 24 lbs., but their use is now almost extinct.

This classification, although it serves its purpose well enough, is somewhat misleading, as the thickness of the case varies in practice, at any rate under modern conditions. In the seventeenth and eighteenth centuries pyrotechnists seem to have had a standard proportion between the case and bore, *i.e.*, the thickness of the case was one-quarter the internal diameter of the rocket.

In modern commercial practice a rocket—say for example of 1 lb.—is a rocket rolled on a former whose diameter is that of the bore of a 1 lb. rocket of standard thickness, but whose outside diameter is governed by the strength of the paper employed in the case.

Several writers on pyrotechny, one Frézier writing in 1747 in particular, have endeavoured to supersede this classification of rockets by replacing it with a series of internal diameter measurements, so far without success. It is hard to supersede the traditions of centuries on a plea of mere rationalism.

Rocket compositions, although containing the same ingredients, namely, saltpetre, sulphur, and charcoal, have them in differing proportions. Broadly speaking, the larger the rocket the greater the proportion of charcoal and sulphur, the variations in proportion being considerable, from the half-ounce rocket mixing of 13 saltpetre, 2 sulphur, and 5 charcoal to the 9 lb. and 24 lb. war rocket, with 13 saltpetre, 3 sulphur, and 4 charcoal approximately, and even higher proportions of the second and third ingredients for special purposes. A larger proportion of charcoal gives a larger tail—a desirable feature in display and signal rockets. Some compositions have a proportion of mealed gunpowder to produce fiercer burning.

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Early makers appear to have used mealed gunpowder and added charcoal and other ingredients to, as it were, dilute the powder and render the deflagration less fierce. Babington (1635) adds charcoal in the following proportion :

1 oz.—4 oz. rockets,	1 lb. of mealed powder to	2 oz. charcoal
4 oz.—10 oz. ,,	1 lb. ,, ,,	2½ oz. ,,
10 oz.—1 lb. ,,	1 lb. ,, ,,	3 oz. ,,

John Bate's compositions are rather erratically arranged ; in some cases he adds the saltpetre, charcoal, and sulphur, and a further addition is " yron scales," presumably to increase the effect of the tail, for which purpose later pyrotechnists used iron filings.

The rocket having been charged to the top of the heading, clay is charged in, forming a diaphragm above it. Earlier practice was to turn down the top edge of the case on the heading composition to form a diaphragm.

The best-known form of rocket is the sky rocket, which is fitted with a stick held in position by having a dowelled end introduced into a rolled paper or metal tube secured to the side of the rocket. The object of the stick is to direct the flight of the rocket, and further serves to hold it in position for firing, being passed through two rings at a suitable distance one above the other on a stake, through which it slides easily.

Sky rockets are fitted with a " cap " containing the " garniture " of the rocket, which may take the form of " stars " or other pyrotechnic effects, or a gun-cotton wad, or similar explosive to make a sound signal, or small cases charged with picrate of potash, producing the well-known " whistling rocket " effect.

The " cap " is either cylindrical or in the form of a truncated cone, with a conical or other top. The cap is burst open

SIMPLE FIREWORKS—ROCKET CLASS

and the contents ignited by an opening charge of powder lighted through a hole bored in the clay diaphragm above the heading, so that when the heading is burnt through the fire may be communicated to the opening charge.

From earliest times the rocket has been the chief item in recreative fireworks; either the sky rocket as we know it to-day or its many modifications and derivatives was the chief constituent of the early displays.

During the sixteenth and seventeenth centuries a display would contain the following items—dragons or similar figures issuing from the scenic castle provided for the display; these would be moved by line rockets. A line rocket has no cap or garniture, the socket usually provided to hold the stick being lengthened, and of sufficient diameter to allow it to slide along a tightly stretched cord passed through it. Pieces of a similar nature to the modern fountain and gerb would be represented by “ground rockets.” This is a rocket less fiercely burning, charged solid, fixed to a support so that it remains stationary whilst burning, the fire being thrown out in a jet. Rockets would also be used to turn such primitive wheels as were exhibited, and to actuate mechanical scenic devices, which are in effect the “turning cases” of the present day. Serpents of fiz-gigs were much used, both as a garniture for rockets, and to give animation to wheels and similar pieces. These were made on the rocket principle, similar to the squib, but slightly more elaborate. A choke was formed between the composition and the “bounce” or powder giving the report.

To-day the ground rocket has developed into the gerb or Chinese tree, fountains of various kinds, the flower pot—of the larger kinds; and among the smaller varieties, the squib with its variations, such as Black Jack and Blue Devil, and the golden rain with its variations.

The modern, or rather more recent, method of heading

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the rocket with a clay diaphragm evidently suggested that the choking of the case might be dispensed with where the composition was less fierce, the necessary reduction of the orifice being produced by a clay diaphragm with a central hole of sufficient size. This method is followed with the gerb, fountains, and flower pot, and in the firework known to pyrotechnists as "fixt"; this unit is largely used in display work to form the fringe frame or lattice effect of a set piece. "Fixt" are made in 1 oz. and 2 oz. sizes, and contain a composition of approximately one part of steel filings to four of mealed gunpowder and finish with a bounce. The origin of the name is uncertain: it may refer to their use on fixed pieces in contradistinction to one revolving, or—as is most probable—was first used to distinguish between a fixed and a moving rocket.

The time of the introduction of the clay choke is uncertain. Jones, writing in 1765, although using clay in the heading of rockets, still choked all cases, but Mortimer (1824) uses it, although Ruggieri (1821), whilst doing the same, appears to think choking preferable.

The former gives instructions for charging the clay solid and boring the central hole; Ruggieri, however, uses a nipple like a much shortened rocket spindle, in which he agrees with the modern practice. This method is also utilised at the present time for small-sized rockets.

Of the fireworks of the fountain class, probably the first to develop from the crude rocket form were the gerb and flower pot. The gerb, or Chinese tree, contains a composition of saltpetre, sulphur, charcoal and iron borings, with the addition—if more force is required, as for instance to turn a device—of mealed gunpowder. Early makers used mealed powder alone and "iron sand," or cast-iron reduced to powder by hammering. This composition is known as Chinese fire, and, as its name implies, was introduced into Europe from the

SIMPLE FIREWORKS—ROCKET CLASS

East. An interesting article appeared in the "Universal Magazine" of 1764, written by a Jesuit missionary on the subject of Chinese fireworks. In it he describes the making of iron sand as follows :

" Old broken or useless pots serve generally for making this sand ; they are broken into pieces of the breadth of the hand, after which, being made red-hot in the fire of a forge, they are thrown in that condition into a trough filled with fresh water, where they are left to cool. Thus calcined, the rust falls off in scales, and they are easily reduced into sand, being first broken into parcels of a finger's breadth. The anvil and hammer used for this purpose must be also of cast-iron, because steel flats the grains of sand. It is necessary that the angles of those grains should be sharp, as it is the angles that form the flowers."

The word "gerb" is derived from the French word meaning a sheaf of corn, and was first applied to water fountains.

The flower pot is charged with a composition formerly known as " spur-fire," from the resemblance in form of its coruscations to the rowel of a spur. The effect produced is one of the most effective when successful, but has the disadvantage for display work that the effect is only appreciated at close quarters. The ingredients used are lampblack, sulphur, red arsenic, saltpetre, with sometimes the addition of charcoal and mealed gunpowder.

Of the smaller works of this division the squib and golden rain are too well known to need description. The squib and its variations have a choked case ; the golden rain and similar works are left with an open bore.

Squibs are generally filled with a composition of sulphur, saltpetre and charcoal, sometimes steel filings, with a bounce of fine-grain powder.

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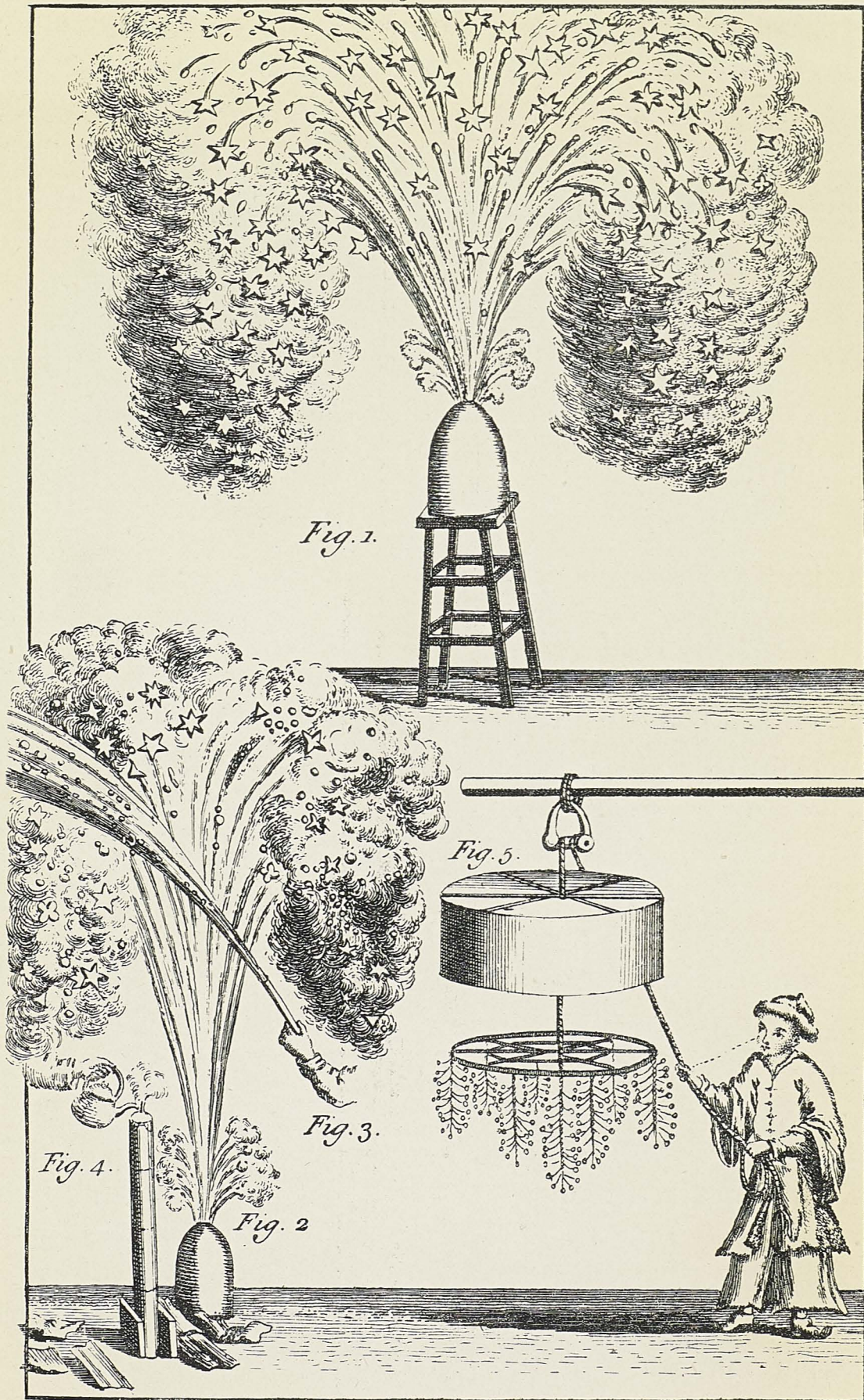
A curious firework, now almost obsolete, for which it is difficult to find a class, is the five-pointed star. This work consisted of a case having a diaphragm of plaster of paris or clay above the filling, below which five holes are bored equidistant and at right angles to the axis. The case is fired in the unusual position of horizontal with the end towards the spectator, the fire playing all round the case, forming a star. The composition used was mealed powder, sulphur, saltpetre, and sulphuret of antimony. Ruggieri mentions this firework under the name "Etoile fixé," and it is mentioned by Jones, writing in 1765, but not by Frézier.

It is hard to believe that this unit was successful, so many factors militating against success, which depends upon the exactly similar jet from each of the five holes. But it is possible that in large geometrical pieces it was at least of use to give an additional effect in what, owing to the lack of variety of the fireworks of the time, must have been rather a monotonous repetition of a few effects. It also would enable small blank spaces to be filled in on set pieces. In a sun or star of the ordinary type, that is of radiating cases, the commencement of the jets must be as far apart as the length of two of the cases, which length is governed by the required time of burning. This leaves a blank centre; the five-pointed star, however, if working correctly, has the jets radiating from a point.

Many of the earlier writers classified fireworks under the heads :—Fireworks for the ground, for the air, and for the water. Those falling in the latter division are only variations of those for the ground, that is to say, a gerb, fountain or other firework is fitted with a float, such as a block of wood, and functions floating on the surface of the water, the effect being greatly enhanced by the reflection.

It is not proposed to deal separately in this work with

Manner of Making Representing Flowers, &c. in the Chinese Fireworks.



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aquatic fireworks unless they have some essential difference from their parallel type for land display.

One unit, of the rocket class, which is so distinct is the "skimmer." This is in effect a stickless rocket with the cap (which is empty) fastened at an angle to the line of the main case. When fired the skimmer, as its name implies, skims over the surface of the water, with occasional dives under the surface in an erratic course. It requires for its safe display a considerable area of water. These are known by French pyrotechnists as "genouillères," from their shape.

Ruggieri and Frézier describe what they call "plongeurs." These are gerbs charged in the ordinary way, except that before each scoop of composition a small quantity of mealed powder is added. This produces a jerky burning, the recoil of each puff of powder driving the gerb beneath the surface of the water; the jet of fire, of course, is sufficient to prevent water entering the case while so submerged. These, and other earlier writers, in their section devoted to aquatic fireworks, give directions for firing ordinary land fireworks on the water, which would almost appear to have been included with the idea of filling space. One item which is generally included consists of directions for firing rockets under water. Jones, under this heading, gives the following directions :

"TO FIRE SKY ROCKETS UNDER WATER.

"You must have stands made as usual, only the rails must be placed flat, instead of edgewise, and have holes in them for the rocket sticks to go through ; for if they were hung upon hooks, the motion of the water would throw them off : the stands being made, if the pond is deep enough, sink them at the sides so deep that when the rockets are in their heads may just appear above the surface of the water ;

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to the mouth of each rocket fix a leader which put through the hole with the stick ; then a little above the water must be a board, supported by the stand, and placed along one side of the rockets ; then the ends of the leaders are turned up through holes made in this board, exactly opposite the rockets. By this means you may fire them singly, or all at once. Rockets may be fired by this method, in the middle of a pond, by a Neptune, a swan, a water-wheel, or anything else you chuse."

It will be seen that the rockets themselves are above the surface, which seems more reasonable than the instructions of some writers, who, to get the effect of a rocket rising from actually beneath the surface, give themselves an infinite amount of trouble to render the case and connections waterproof. The effect seen from a short distance is identical.

CHAPTER II

SIMPLE FIREWORKS—SHELL CLASS

WE now come to a distinct class of fireworks, those whose functioning depends on the propulsion of gunpowder. The first and parent of this class is the shell or bomb.

The original name of the shell was "air balloon," which is now obsolete. Some writers have been misled by its appearance in old amusement announcements into thinking a balloon ascent was referred to, or that a balloon carrying fireworks was to be exhibited, at dates considerably before the invention of gas or hot-air balloons.

In this connection it is interesting to note that Ruggieri claims that his father was the first to release a balloon carrying fireworks in 1786.

As we have seen, the military use of shell dates from at least as early as the middle of the sixteenth century.

Both Babington and Bate, writing in 1635, give instructions for making shell, and although the book of the former is more advanced in this particular matter, he is, generally speaking, considerably more primitive.

Babington describes a hollow sphere of canvas, a part of which is filled with a slow-burning composition, the remainder being filled with stars and grain powder, the canvas is pierced to expose the slow composition. The shell is fired from a mortar having a touch-hole. The following are Babington's instructions in the matter :

"Load your mortar piece with one ounce of corne powder, putting after a wadd and tampion, and put on your ball with the vent towards the mouth of your piece : so

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elevating your piece to the zenith, you may proceed to the firing of it, which must be after this manner : provide two matches ready lighted, having one in each hand, and first fire your ball with one hand and presently give fire to your piece with the other, alwaies holding your head under the horizontall line of your piece, for fear the blast annoy you : this having done you shall see your ball mount very high with a fair taile of fire, and when at its highest, shall break forth into a goodly showre of starres."

This somewhat unconvincing account gives one to wonder if the worthy gunner had indeed fired a shell such as he describes, and if so, whether he was not more than "annoyed" at the result. He gives the lifting charge as exactly one ounce, but gives no indication of the size of the shell or mortar. It seems probable that he had never seen a shell of this nature, and was giving his idea of it without practical experience ; this is the more curious as, generally speaking, his book is wonderfully advanced for the period, and indicates personal experience of the matters under discussion.

John Bate, although less fluent, gives greater indication of practical knowledge of the matter. His "balloone" is rather oblong in section, and is made by rolling canvas on a former, using eight or nine turns. The ends are choked in the same way as a rocket case, one end being choked on to a "little cane rammed full of a slow composition." The shell is placed in the mortar with the fuse downwards, which is ignited by the flash of the mortar charge. Bate takes the precaution of having a time fuse at the touch-hole of the mortar, and concludes his instructions for firing by saying, "and while that burneth, retreat out of harms way." Altogether a more practical and convincing description.

Frézier (1747) makes the following prefatory remarks to his chapter on shells :

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“The name of ‘balon’ is given to a firework which is thrown into the air like artillery bombs for war, so that they are often given the same name as bomb.

“The difference between this firework and a bomb is not only that the former is to amuse and that the latter to destroy, and that the one is made of iron, and the other of wood, linen, or cardboard, but principally because the latter is made to burst and throw out its garniture at the point of the highest elevation, while the war bombs do so at the moment of their fall to the earth, also the war bombs are thrown towards the horizon, while the firework bombs are thrown vertically or nearly so.

“The fireworks differ also from the war bombs in shape, the former being not always spherical, as the latter are.

“We must therefore understand by the name of shell a firework of which the effect and principal beauty is that while going up in the air it only shews a small stream of fire, which multiplies itself suddenly into a great number of others at the moment of its highest elevation, which causes a pleasant surprise.

“As this firework does not lift itself, but is thrown by impulsion the same way as a bomb, it can, like the latter, only be fired from a mortar.”

He describes two shapes of shell, the spherical and cylindrical, with a hemispherical end, which shape is more convenient where the contents are long in form, as rockets, Roman candles, etc. He attributes the introduction of this shape to Siemienowitz, who, he says, made the cases of wood. He himself, however, adopts the modern method, as he does with the fuse, which he calls the port-fire. The lifting charge, however, is placed in the mortar separately from the shell and ignited at a touch-hole, in which, as will be seen, he differs from modern practice.

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He gives a list of garnitures or fillings, which are interesting as showing the practice of the day :

“ The first is the one which gives the effect of a water-fall or head of hair. This is made of thin narrow tubes, or if possible, of thin canes, cut to the length of the shell, and filled with a slow-burning composition made of three parts of priming powder, two of charcoal, and one of sulphur, damped with a little petroleum, and capped with a paste made of powder crushed in distilled water or spirit and afterwards dried. All these are put in the tube, around the one which is used for the passage of the port-fire.

“ When it is full the loaded port-fire is introduced, and pushed so far that it reaches the frame, and when it is touching the lid, this lid must be glued by the rough ends to that of the tube, and the shell is finished.

“ As it is rather heavy, it is advisable to adopt means for its resisting the shock of the lifting charge of powder which drives it out of the mortar, by strengthening it with a covering of linen strips, which should be stuck on to the shell by means of a paste, composed of two-thirds of flour paste, and one-third of glue.

“ Unless this is done it often happens that the shell bursts before it rises in the air.”

The second consists of serpents, the third of “ saucissons volans,” similar to the “ fiz-gig ” of Bate ; the choke in the middle between the composition and the bang being varied in position so as to produce a succession of bangs. The vacant spaces left over in the shorter may be filled with stars.

The fourth is of stars arranged in beds of grain powder ; the interstices being filled with a mixture of mealed powder and charcoal. The fifth of “ light balls,” and for the sixth he describes “ the manner of making figures and various shapes

SIMPLE FIREWORKS—SHELL CLASS

in fire appear in the air." These letters are made on a frame covered with composition, and are consequently limited to a size to the internal diameter of the shell, that is, less than eight inches. It seems improbable that they could be distinguished satisfactorily at the height of a shell's trajectory, besides which the difficulties involved, as he himself explains, are very great, which no doubt explains the fact that this idea is now obsolete.

Under the heading "Double and Triple Balloons," this writer describes the method of placing shell of smaller size inside a larger. The bursting of the first shell lights the short-time fuse of the contained shell, which falls some distance and bursts. With the triple shell this action is repeated.

Jones (1765) divides shell into four kinds, namely, "illuminated balloons" filled with stars; "balloons of serpents," "balloons of reports, marrons and crackers," and "compound balloons." The last description is misleading, as the balloon is not compound but the contents are varied, as for example, the contents of one specified ten crackers of six reports, twenty golden rains, sixteen two-ounce cases charged half-inch with star composition and bounced, two ounces each of brilliant, blue, coloured tailed, large string and rolled stars. It is hard to believe that this writer had ever seen a shell fired in this manner, the result would have been mere confusion. The star compositions of that date were very rudimentary, the colours when seen from the distance of a bursting shell were indistinguishable.

One interesting detail in Jones's work is the classification of sizes. The smallest shell mentioned by him is the "Coehorn Balloon"; he does not give the size, but it is given in the "Military Encyclopedia" as $4\frac{1}{2}$ inches. This corresponds to the $4\frac{1}{2}$ -inch of to-day. The name was apparently derived from

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a Dutch military engineer of that name. The next size is the royal 5½-inch, and above that 8-inch and 10-inch.

Ruggieri (1821) is the first writer on the subject to have the shell and lifting charge in a unit as is the practice to-day, which indicates constructionally a great advance over his predecessors, although the fillings show little progress.

The modern shell is arranged with a "lighter" of quickmatch, long enough to reach from the top of the shell when in position in the mortar to a sufficient distance outside the mouth to enable it to be ignited without danger. The lighter fires the time-fuse in the top of the shell, and at the same time two pieces of quickmatch which run round the shell in grooves worked in the paper shell case, and ignites the lifting charge, which is contained in a flannel bag, or in the case of small shell, a paper cone.

The lifting charge projects the shell into the air and the time fuse, which is arranged to burn through at the top of the shell's flight, ignites the bursting charge which opens the shell and fires the contents.

The modern varieties of shell are almost infinite. Colours have been brought to a wonderful pitch of depth and brilliance, besides various kinds of fire for stars, producing stars with tails of the same and contrasting colours.

Another class of shell, which might be called the compound, consists of shell filled with fireworks of other kinds—Roman candles, tourbillions, wheel-turning cases, small shell, and what gives undoubtedly the most dramatic aerial effect yet devised, with rockets. The "thunderbolt," a shell 16 inches in diameter, containing a hundred 4-ounce rockets, has always been a popular feature of the Crystal Palace displays.

Another variation of the shell is the comet, which is in effect a small shell (generally about three inches) with an

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exaggerated fuse of brilliant fire, which leaves a heavy tail during the comet's flight. These are usually fired from either side of the firing-ground in rapid succession, producing an aerial arch, and opening just after having passed each other.

The aerial maroon consists of a maroon fitted with a lifting charge and time fuse.

CHAPTER III

SIMPLE FIREWORKS—MINE CLASS

THE next group of fireworks is what may be called the " Mine " class, and has some of its members amongst the earliest firework units.

To-day a mine consists of a quantity of small effects such as stars, crackers, squibs, etc., blown simultaneously from a case, or in display work—from a mortar. In the latter event they are made up into bags with the lifting charge below, and are known technically as " bags."

The " Mine of Serpents " and " Jack-in-the-Box " as sold in the shops consist of a rolled paper case which acts as the mortar, at the bottom of which is a lifting charge. This case has a light strawboard cover with a central hole, through which passes a case charged with a golden fountain composition, the lower end of which is not—as is generally the case—" clayed." The space round the central case is filled in with squibs or crackers. When lighted the fountain case functions in the usual way, but when finished ignites the lifting charge, which lights and blows up the contained fireworks.

A very early reference to the " Jack-in-the-Box " is by John Babington (1635). In Chapter XXXVII he says : " Another which I call Jack in a Box. The order of making this is after this manner : provide a box of plate, of what largeness you please—then putting in a quantity of corn powder or powder dust (in the bottom of the box) you shall fill it with figsigs or serpents, leaving a case in the middle for a cane to go through to the bottom, which cane must be filled with a slow receipt, in which you shall put a quantity of champhire but no oyles,

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in regard of the narrow passage it has to burn without any other vent." He then describes fitting the pasteboard top and concludes : " and light your cane, which will appear like a candle, and after a pretty distance of time you shall heare a sudden noyse and see all those fising flying some one way, some another. This toy has given great content to the spectators."

Frézier calls mines " Pots à feu " or d'aigrettes," which, he says, were three, four, or five inches in diameter, and twelve to eighteen inches in length. When fired in batteries they were called " Pots de brins."

The smaller kind were ignited at a vent formed by choking the case, the vent—when the case was in position—pointing downward. The larger sorts were lighted from above, and were practically the same as the Jack-in-the-Box, with the difference that there was a case similar to a shell fuse instead of the central Roman candle.

Jones' description of " Pots d'aigrettes " and " Pots de brins " are similar, only that he fires the former with a Roman candle in the centre of the central mortar of a group with a lighter from it to each of the others, so that at the finish of the Roman candle the mortars are discharged simultaneously.

An elaboration of the " Jack " is the " Devil-among-the-Tailors," which is the same device surrounded by Roman candles.

The next fireworks in this class—the Roman candle—is one whose genesis presents a most interesting study. From the evidence available there seems no doubt that this firework, in spite of its name, originated in this country.

The first mention of anything resembling it is found in Babington's book. He describes what he calls " a trunck of fire which shall cast forth divers fire balls." It is one of a class, apparently in favour at this time, intended to be carried

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on a staff, and known collectively as " fire lances " or " clubs " (the former name is not to be confused with the lances used in set-piece work).

The particular one under consideration, although it is very large, being four inches bore, and only emits two balls or stars, is undoubtedly the prototype of the " Roman."

Bate describes a somewhat similar lance with the difference that " petards " or single crackers are substituted for stars.

This was in 1635. Over one hundred years later, Frézier describes an almost exactly similar firework under the heading " Artifices Portatifs," which name he adopts instead of the old name " Lance à feu," in order to avoid confusion with the lance as known to-day, which was then coming into use.

This is the only mention he makes of anything that can be considered to even remotely resemble a Roman candle, and as he refers to several other writers, a justifiable inference seems to be that neither he or they had any knowledge of such a firework. Had he known of it, such is its popularity he would certainly have mentioned it.

Eighteen years later Jones describes exactly the Roman candle as made to-day, to which he gives the name " Fire Pump."

" Pumps " and " Pumps with Starrs " occur in the description subjoined to engravings depicting English peace displays in 1697 and 1713; there can be no doubt that the reference is to Roman candles or the earlier development of them.

When, however, the elder Ruggieri came over to this country in 1749 to conduct the Aix-la-Chapelle peace display in Green Park, in conjunction with Sarti, no firework of this nature appears in the programme of the display.

Here we have two pyrotechnists who can be considered to represent the best skill of France and Italy; in fact, it

SIMPLE FIREWORKS—MINE CLASS

was Ruggieri whose arrival in France from Italy in or about 1735 marked the great advance in pyrotechny in the former country. Yet the " Pump " does not appear in this great display planned and executed by them, although for years it had been a popular item in displays in this country. The obvious reason for this omission is that they did not know of it.

In the early part of the nineteenth century the name " Roman candle " comes into use both here and in France. The " English Encyclopædia " of 1802 still uses the expression " Fire Pump," but this is probably because their article is copied almost verbatim from Jones' book. The name Roman candle, however, appears in an advertisement of a display at Ipswich by William Brock in 1818, and Ruggieri the younger uses the words " chandelle romaine " in his book of 1805.

How this firework received the name Roman is obscure ; it may have been affixed by one of the many Italian pyrotechnists working here, or it may have had political or religious significance.

A firework functioning in the same way as a Roman candle is the Italian streamer, which has stars of a composition containing lampblack, which burn with a gold fire and leave a tail in their flight.

The Roman candle of the present day is made with an almost endless variety of stars, but those in use when the name was first introduced were of very simple character. Coloured stars, as accepted to-day, were not introduced until about the thirtieth year of the last century.

The compositions given by Jones and Ruggieri would produce approximately the same effect as the Italian streamer star of to-day, but with little or no tail.

Lampblack compositions appear to have been introduced into Europe from the East, and there seems to be no reason why Italy should have had them before this country, or that

PYROTECHNICS

the introduction of lampblack into Roman candle star composition should be credited to Italy.

It seems more probable that the name Italian streamer was attached to that firework in this country to distinguish it from the Roman candle with tailless stars, and under the mistaken idea that the "Roman" was a foreign importation, or that it would be more acceptable if labelled with a foreign name.

As we have said, the modern Roman candle is made with stars of very many varieties, but whatever kind of star may be used, the method of filling is the same.

The principle on which the Roman candle is constructed is as follows: The case is charged with a series of repetitions of the following—Roman candle fuse, "dark fire," star, blowing charge. These are repeated as many times as the case will hold, and function thus—the fuse burns with a fountain effect, and upon being exhausted lights the "dark fire," which lights the star, flashes round it and fires the blowing charge which propels the star from the case. The blowing charge also ignites the next layer of fuse, and the effect is repeated.

In filling the case different sized scoops are used for the blowing charge, which is of fine-grain powder, the smaller scoops being used at the lower portion of the case. This is done so that the stars may rise to approximately the same height; the charge at the bottom acting through a greater distance, naturally acts more effectively and less is required.

Earlier pyrotechnists, in addition, as a means of regulating the height of the stars' flight, made the stars of differing sizes; this under modern manufacturing conditions would be impossible, and has been abandoned.

Roman candle fuse is composed of sulphur, charcoal, saltpetre in the proportion of 4, 8, 15. The "dark fire" is of mealed powder, with a small admixture of charcoal.

SUPERIOR Fire Works,

AT THE

ROYAL WILLIAM,
Bowling Green, and Tea Gardens,
IPSWICH,

ON TUESDAY AND WEDNESDAY EVENINGS, 7th and 8th of JULY, 1818,
BY

MR. BROCK,

ENGINEER,

Whose indefatigable study and attention to his profession, enables him to produce devices hitherto unknown to the Art, and with a richness and brilliancy surpassing all precedent.

PREVIOUS TO THE EXHIBITION IN THE GARDEN,

A GRAND DISPLAY OF VARIOUS KINDS OF

WATER FIRE WORKS,

ON THE RIVER.

Order of Firing.

FIRST DIVISION.

- 1 A Battery of Maroons, or imitative cannon
- 2 A Bengal light
- 3 Sky Rockets
- 4 A Saxon Wheel
- 5 Tourbillions
- 6 A regulating piece in three mutations, displaying a Vertical Wheel, a catenation diamond, and a figure piece, of straw and brilliant fires
- 7 Line Rockets
- 8 Phenomenon Box and Mine
- 9 Sky Rockets
- 10 A Metamorphose with alternate changes, and a beautiful display of Chinese lattice work

SECOND DIVISION.

- 11 Sky Rockets
- 12 Horizontal Wheel with Roman Candles and Mine
- 13 Tourbillions
- 14 A regulating piece in two mutations, displaying a Vertical Wheel, and a superb display of chequer work, in straw and brilliant fires
- 15 Line Rockets
- 16 A regulating piece in three mutations, displaying a Vertical Wheel, changing to five Vertical Wheels, & a figure piece in straw & brilliant fires
- 17 Grand Battery of Roman Candles
- 18 A regulating piece in four mutations, displaying a Vertical Wheel, a brilliant Sun, five Cobourg Union Stars, and a figure piece of straw and brilliant fires
- 19 Sky Rockets
- 20 A regulating piece in three mutations, displaying a Vertical Wheel changing to a Pyramid of Wheels, and a superb shower of fire

ADMISSION, 1s. each.

Gardens open at half-past Seven, and commences at Nine o'clock precisely.

DECK, PRINTER, IPSWICH.

SIMPLE FIREWORKS—MINE CLASS

Another firework which is probably a development of the Roman candle is the jewel fountain. This consists of a fountain mixture of saltpetre, sulphur, and charcoal, to which is added granules of star composition, which are thrown out by the force of the fire, giving a fountain effect in which appear variously coloured points of fire.

CHAPTER IV

SIMPLE FIREWORKS—SAXON & LANCE CLASSES

THE fireworks which form a class by themselves are the Saxon or Chinese flyer, and the tourbillion. Both of these consist of a single case made to revolve in the plane of its axis by jets of fire projected through a hole at right angles to the axis.

Saxons revolve about a nail driven through the case into a post or other support ; they are charged with a composition of mealed gunpowder, saltpetre, and sulphur.

The case is charged thus: the lower end is firmly "clayed" and the composition is charged up to a point about $\frac{3}{8}$ inch below the centre, clay is then charged for $\frac{3}{4}$ inch, and again composition to within a short distance of the top, which is again firmly clayed. Two holes are bored near each end on opposite sides of the case, and a third hole is bored through the centre of the case at right angles to the other two and of sufficient size to take the nail or spindle on which the case revolves.

The two holes at the end may be connected with match to light simultaneously, or the time of burning may be lengthened by leading the second half from the lower end of the first lit. In the larger sizes, and generally in display work, a small case charged with a colour composition is attached to the side of the case, producing a ring of colour inside the fire of the saxon.

A smaller and cheaper form of saxon is what is in effect half of that described above, the nail being at one end and the propelling hole at the other.

Formerly saxons for display work were made with a wooden



Rocket Charging.



Filling Roman Candles.

SIMPLE FIREWORKS—SAXON & LANCE CLASSES

centre, on which the two halves, which were charged separately, were fitted, and to which the colour case was secured by a nail.

The tourbillion is a development of the saxon ; instead of the central spindle a piece of curved wood is secured to the case, forming a pivot on which to revolve when lying on a flat surface, and two additional holes are bored on the under side of the case, so arranged as to light when the case has sufficiently rapid revolution and project it into the air.

Jones describes tourbillions as made to-day, also saxons under the older name of Chinese flyer. In addition, he describes what he calls "table rockets," which resemble four double saxon cases filled to a centre, which has a projecting cone upon which the device revolves.

He says that "table rockets are designed merely to show the truth of driving and the judgment of a fireworker, they having no other effect when fired than spinning round in the same place where they begin till they are burnt out, and showing nothing more than a horizontal circle of fire," but afterwards adds that "these rockets may be made to rise like tourbillions by making the cases shorter and boring holes in the under side of each case at equal distances ; this being done they are called 'double tourbillions.'"

Frézier shows tourbillions as at present manufactured, which he calls "tourbillion de feu" or "soleil montant," but the nearest device he shows to a saxon is similar to Jones's table rocket, made to revolve on a spindle, and having several holes bored down the side of each case, presumably to produce more effect. These he designates "tourniquets" or "soleils tournants."

He also illustrates two ordinary rockets mounted on a centre similar to that of a double saxon. This he calls "baton à feu," and describes that one case lights after the other is burnt

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out, and one gathers that the device is intended to revolve, but how it can be made to do this by fire issuing radially is not apparent.

The word *tourbillion* is the French for a whirlwind, and is applied by Ruggieri to a compound firework, which will be considered later under that head.

What we know as *tourbillion* he names "*fusée de table*" (a table rocket), and adds that they are commonly called "*artichauts*."

The success of all the above, in common with rockets, depends on careful and experienced construction and strength of the case, and it is indeed curious that Jones describes the rolling of the cases for these fireworks without paste except on the edge of the paper. It seems incredible that an experienced pyrotechnist should make such a mistake, and one is almost inclined to agree with Kentish (1878), who says of Jones's book: "The greater portion of it is absurd and impracticable, and shows it was written by a person who undertook to teach what he had not learnt." Nevertheless Jones's book, as Kentish says, has been copied by almost every book published since, just as his own matter was largely pirated from previous works. In fact, for a century and a half the plates illustrating pyrotechnic works were in a great degree fac-similes of one another.

The catherine wheel, or, as it is sometimes called, the pin wheel, is a rotating firework of simple, as distinct from compound construction, and should therefore be included in this class.

It consists of a long, thin case of small diameter, charged with a composition of sulphur, saltpetre, and mealed gunpowder. This case is wound round a circular block of thin wood, with a hole in the centre through which a pin or nail is passed, forming a pivot upon which the wheel turns.

SIMPLE FIREWORKS—SAXON & LANCE CLASSES

The case of the catherine wheel, unlike any firework we have considered up to the present, burns down as the composition is consumed, and for this reason it may be included equally well in another small class of fireworks. This class includes the lance, the port-fire, the starlights, feathers, and the colour cases used on wheels and saxons, etc.

The lance is used in display work in greater numbers than any other unit. Some idea of the quantity used may be gathered from the fact that on one of the battle set pieces shown at the Crystal Palace as many as thirty thousand lances are consumed in a single display.

Lances consist of thin paper cases about the diameter of a lead pencil, filled with colour composition, and primed, to facilitate the lighting, with mealed powder damped with water. This sets and further serves to retain the contents of the lance, which are not compressed solid as are fountains, rockets, etc.

The port-fire is used as a means of lighting the pieces, etc., of a display, and in the last century for military purposes; its composition consists of a mixture of saltpetre, sulphur, and mealed gunpowder. It was formerly known as a blue candle.

The starlight and feathers, as are the squib, golden rain, etc., are of the garden type, and are not used in display work, as although burning with pretty effect, it is not distinguishable at any distance.

The feather and starlight compositions are similar to that of the flower pot, but the cases are smaller, that of the feather being catherine wheel pipe, but naturally not bent—the ends are closed by “dubbing.” This is a method usually adopted for closing the ends of “small goods.” The end of the case is introduced into an opening formed by opposing V-shaped notches in an upper and lower series of steel plates, the upper set being then forced down. The result is to constrict the end

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of the case, which is then dipped in a mixture of sealing-wax and glue.

Under the same head fall the Light group, which are wide and comparatively thin cases filled with coloured or “ bright ” (as white composition is known in the trade) composition. They are used either for illuminating as Bengal lights, or for signalling purposes ; if for the latter, they are generally provided with a wooden handle and some means of self-ignition.

The name Bengal light is probably based on the use of Bengal saltpetre, and does not indicate their origin in that province.

CHAPTER V

COMPOUND FIREWORKS

COMPOUND fireworks are those which are composed of a number of simple fireworks or units fixed to a framework or other device so that they produce a more elaborate effect than do single fireworks.

Probably the earliest form of compound firework was the wheel. After the sky rocket had become an established fact, it was a small step to tie rockets round a wheel, so that when fired they caused it to revolve.

Babington gives several devices based on the idea of imparting movement to a wheel by rockets: he describes horizontal and vertical wheels, which appear to be the same piece fired either horizontally or vertically. In neither case is there any further effect than the fire from the rockets tied to the periphery. His illustration shows no less than sixteen rockets to fire singly in succession, which would, by modern standards, make a rather lengthy and monotonous piece. He also describes ground wheels, which consist of two wheels fitted to an axle with a smaller wheel placed centrally between them. The centre wheel has rocket cases fitted to it, causing the whole arrangement to revolve and run along the ground. As an alternative he suggests substituting cases secured to the axle without a central wheel, so arranged that one being burnt out the second burns in the opposite direction and reverses the direction of the wheels. The device is now quite obsolete.

One interesting point is the method of communicating fire from one case to the next; quickmatch, as used to-day, had not then been invented. His method was to fasten the cases head to tail a short distance apart by wrapping and tying

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paper round in the form of a tube, the space so formed containing some mealed powder.

He also describes what he calls fixed wheels, which are in effect the fixed sun of to-day; that is, a framework with cases arranged radially so that the fire is thrown out from the centre.

As variations of the above, he suggests various effects such as "a fixed wheel which shall give divers reports," "which shall cast forth divers fisgigs, and likewise as many reports or breakers," "which shall cast forth many rockets into the ayre." The latter is evidently the prototype of a piece known later as the rocket wheel, popular for some time, but little used at the present, the objection to it being that there is no control over the direction in which the rockets fly from it. The wheel revolves horizontally, and projects a series of rockets into the air as it revolves.

During the following century, as compound fireworks developed in this country, the Italian and French nomenclature was introduced, many of which survive at the present time.

The pyrotechnists of the eighteenth century seem to have delighted in inventing new terms, possibly with the idea of impressing the layman. Frézier, writing over a hundred years later than Babington, records very little advance in revolving fireworks, except in the matter of names. He classifies all revolving pieces as girandoles. This word appears in pyrotechny very frequently; curiously enough, nearly every writer has attached a different meaning to it. Frézier explains that the word is derived from girare—to revolve or gyrate, from the Greek.

Bate applied this meaning to it. He says, "How to make gironels or fire wheeles." He is, however, the only English writer to do so; others use it to mean a flight of rockets, and occasionally for an elaborate fixed piece of the fountain type.

COMPOUND FIREWORKS

Ruggieri and Sarti, both Italians, used it in the sense of a "flight" of rockets in the programme of their Green Park display in 1749. Ruggieri the younger, however, applies it to a specific kind of revolving firework in his book, and introduces a new word—*girande*—to which he applies the same meaning as the one generally accepted in this country for *girandole*. The confusion of these two words, which have the same derivation, may be the explanation of the duplication of meaning, or it may lie in the fact that the name was also applied to the rocket wheel previously mentioned, which both revolves and throws up rockets.

Frézier shows a wheel similar to that given by Babington, and variations on the double saxon, a fixed sun also, as do most early writers, double line rockets to run backwards and forwards and variations. These latter, which appear to have been very popular at this period, were known in France as "*courantins*." Bate calls them "*swevels*," other early writers "*runners on the line*."

The above-mentioned, together with some rather intricate but impracticable appearing water devices, make up the compound fireworks in Frézier's book.

It seems, however, that he must have been behind his day in this branch of the art, as the Aix-la-Chapelle peace display appears to have included several elaborate pieces which, even allowing for the usual exaggeration of the programme, must have required considerable skill and knowledge in construction. These were mostly what were called regulated or regulating pieces, generally described as of a certain number of mutations. The pieces were, and are, although the old descriptions are now dispensed with, so constructed that after being lit they go through a series of alterations in form and movement without further attention.

Some of those described in old works would seem to have

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required more than a slight element of luck for their successful performance.

To-day it is often found more advantageous to make a second lighting in cases where there is a danger of premature ignition, the effect to the spectators being identical, and the successful functioning of the piece secured. This does not apply to all pieces of this nature, as with modern safety fuse the pyrotechnist has considerable advantage over the earlier practitioners.

The modern spectator is only concerned with the effect produced, not by the means adopted to produce it. It is difficult to-day to realise the position occupied by the pyrotechnist of the eighteenth century. He carried out his work personally, with of course trained assistants, and occupied a position similar to the artist or sculptor. Each piece was looked upon as a work of art, the personal effort of the pyrotechnic artist. Ruggieri gives some idea of this in the following passage from his book :

“ It was in the month of July, 1743, that my father and my uncles Ruggieri exhibited for the first time at the Theatre de la Comédie Italienne and before the King, the passage of fire from a moving to a fixed piece.

“This ingenious contrivance at first astonished the scientists of the day, who said when it was explained to them that nothing could be more simple and that any one could have done it at once.”

He then explains the method of construction, which is to lead from the back end of one of the turning cases through the hollow centre of the axle to the lighter of the fixed piece situated behind it.

The development of fixed and mechanical pieces was made possible by the introduction of quickmatch.

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When this actually took place is uncertain. Frézier describes its making similarly to that in use to-day, under the name of "étoupilles." Bate uses the word "stouple," evidently a corruption of the French. He gives no actual description of the making of this, but it appears to be of "cotton weeke" dipped in "aqua vitæ wherein camphire hath been dissolved." This would produce only a slow-burning match unless it was his intention to use it wet, in which case the burning of the spirits of wine might quicken the effect. It would, however, be quite out of the question to construct a piece of any elaboration with such materials.

Quickmatch is manufactured to-day in the following manner. Cotton wick is run through a pan containing a paste composed of gunpowder and starch. It is wound on a frame six feet in length, dusted with mealed powder and dried. When dry it is cut off the frame and threaded into paper tubes or "pipes" of larger diameter, leaving an air space round the match.

Before threading in the tubes it is known in the trade as "raw match," and is used for priming and similar uses, and in this state will only burn quite slowly.

Quickmatch is used to connect the units of all pieces. Display cases have a "cap" formed of a few turns of paper pasted on the case at the lighting end. When a piece is fitted up the cases are tied to the cleats provided to receive them on the framework; they are then "lead up." A length of quickmatch has a small piece cut out of the pipe to allow the fire to flash through, it is then doubled at that point and inserted in the cap, which is gathered in and tied round securely. This is continued round the piece, each case having match entering and leaving the cap, and in some cases a further length connecting one series with another. This leading up of set pieces is work requiring skill and knowledge which is only

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gained by experience. An amateur at a first attempt might possibly be successful in lighting all the cases on a piece, but he would be very unlikely to produce that instant and symmetrical ignition which denotes the skilled pyrotechnist.

The smaller wheels have turning cases, that is, small rockets to give them motion ; these burn through very rapidly, and the continuation of movement is provided for by capping the turning cases at either end and leading them up vent to head in series ; the motive power for the larger display pieces is provided by gerbs, which, from the nature of their fire, give more effect than would rocket cases, and have the further advantage of burning longer.

It would not be possible in the present work to give a complete catalogue of the varieties of pieces which have been produced, but the list given by Ruggieri is typical of the whole, and includes many of the smaller compound pieces in use to-day for shop and small display work.

The larger display pieces are generally designed and re-designed season by season by pyrotechnists, and are certainly being elaborated and improved. They, however, fall generally into certain classes in the same way as do those given by Ruggieri. His classification is as follows :

1. Stationary fireworks.
2. Fireworks turning vertically.
3. Mixed fireworks or fixed and turning.
4. Fireworks turning horizontally or on a pivot.
5. Built-up pieces turning on a pivot.
6. Cut-out pieces and transparencies.

Of these, the last mentioned class are now obsolete : they consisted of transparent and silhouette pictures or designs illuminated from behind. He also includes both simple and

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compound fireworks in each class, but as the former have already been dealt with they will be ignored here.

Class 1. (1) Glorys, fans and “*pates d’oie*” or goose foot, synonymous with our expression crow’s foot.

Glory was a term used also in this country to signify fixed suns, as mentioned above. Fans were cases five or more in number, arranged as the name indicated, and *pates d’oie*, three similarly arranged.

(2) Mosaïques. These are geometrical designs formed by arranging gerbs or fixt on framework, so that their fire forms a symmetrical pattern. The effect is heightened by saxons in suitable positions, and in large devices of this nature, small wheels, also formerly, the now obsolete fixed or five-pointed star.

This type includes what are now called “lattice poles,” a series of poles provided with cleats so that the fire of the cases crosses, forming a lattice of sparks; also the more elaborate “carpet piece.”

(3) Feux croisés. These were similar in conception to the above, except that the design is circular or based on the circle or wheel form; this type is represented by the “fixt piece” of to-day, which is constructed up to considerable dimensions, the large fixt piece at the Crystal Palace often measuring sixty feet across the fire.

(4) Palm Trees. These consist of a framework intended to suggest the form of a palm, provided with cleats to take the cases.

(5) Bouquets. These he describes also as a kind of tree different from palm trees; his illustration shows that they were similar to the modern lattice-pole with the difference that the cleats were not symmetrically arranged.

To-day the word bouquet is applied to Roman candles arranged in what he called “*pates d’oie*.”

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(6) Cascade. This device needs no explanation. He says that Chinese fire is the best composition for such a piece; this remained true up to the introduction of the aluminium into pyrotechny, when the "weird white waterfall" became a feature of the Crystal Palace displays, being 200 feet long and 90 feet high.

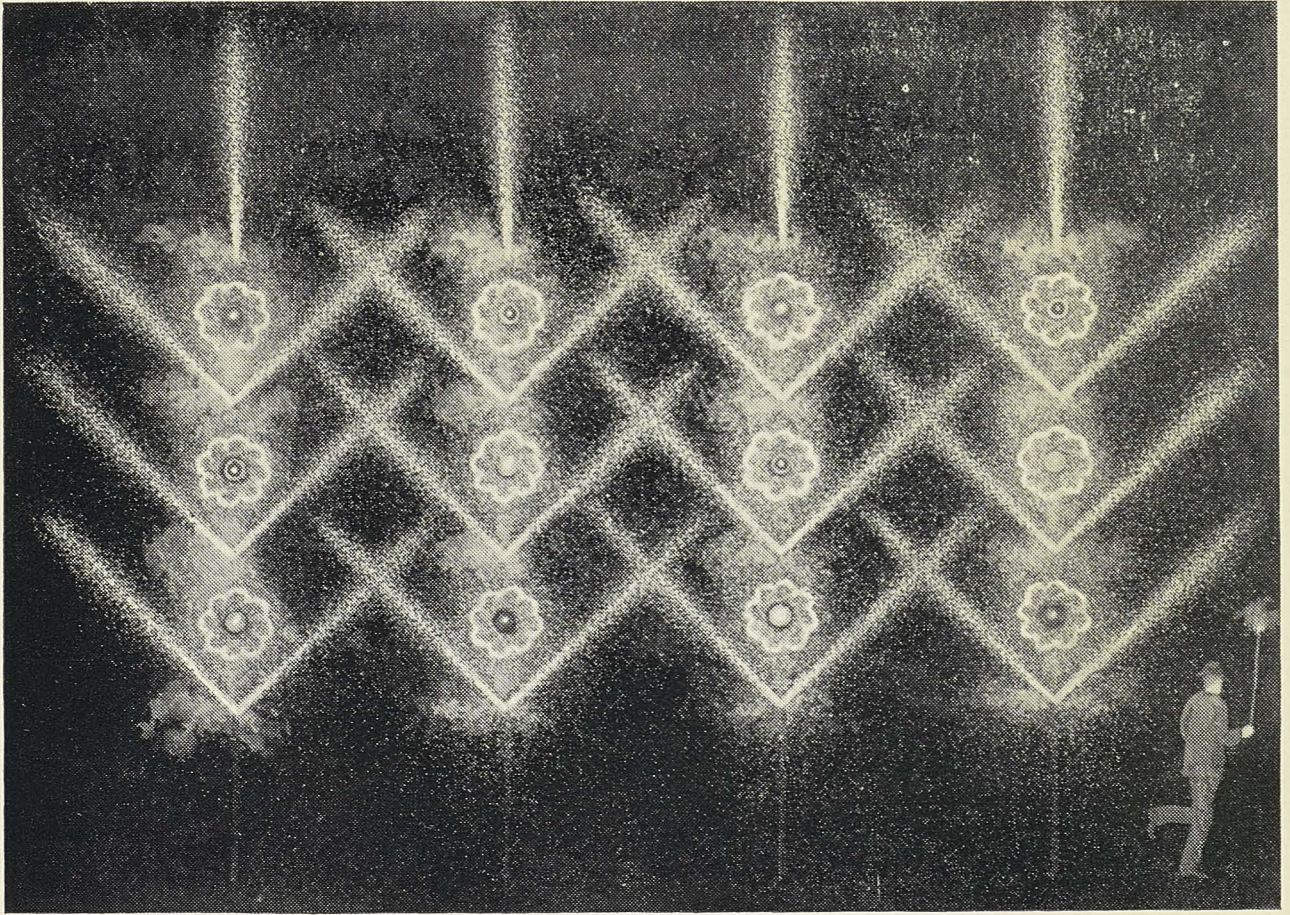
(7) Decorations in coloured fire. This heading introduces the lancework set piece of to-day.

The development of this branch since 1865 has been very marked. As will be seen from the description of the lancework pieces carried out at the Crystal Palace, the subjects dealt with have been of extraordinary variety. Up to the beginning of the nineteenth century pyrotechnists had failed to realise the possibilities of lancework. This was undoubtedly due in a great measure to the fewness of colours available. Ruggieri appears to have used lancework to outline architectural designs, evidently a survival of the temples or theatres of earlier years. In his time, and even as late as the middle of the nineteenth century, any subject of a pictorial nature was depicted by the use of scenery or transparencies. Lancework was, as Ruggieri describes it, merely "decorations in coloured fire." The lances of his day were considerably thicker than those at present in use, which are about the diameter of a lead pencil. They were also spaced further apart and were in some cases "bounced," as are fixed cases of the present day.

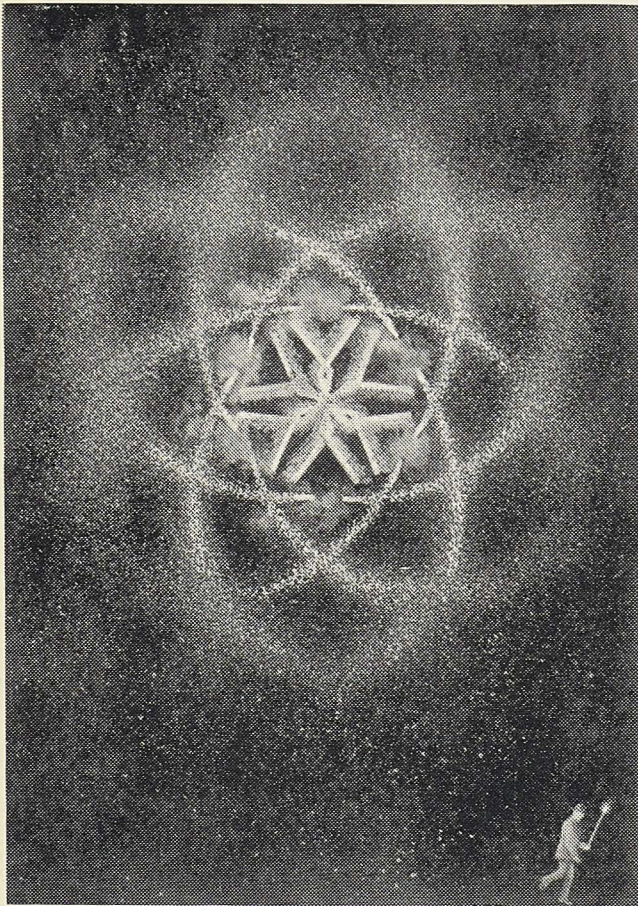
The modern method of constructing a lancework set piece is as follows: An outline drawing of the subject is made in which all unnecessary lines are eliminated. This is ruled in square of such size that in the proportion one square to a foot the completed piece will be of the size required.

Frames are then laid out on the drawing-floor: these are of light battens forming foot squares, and of a convenient size for handling, generally ten feet by five feet.

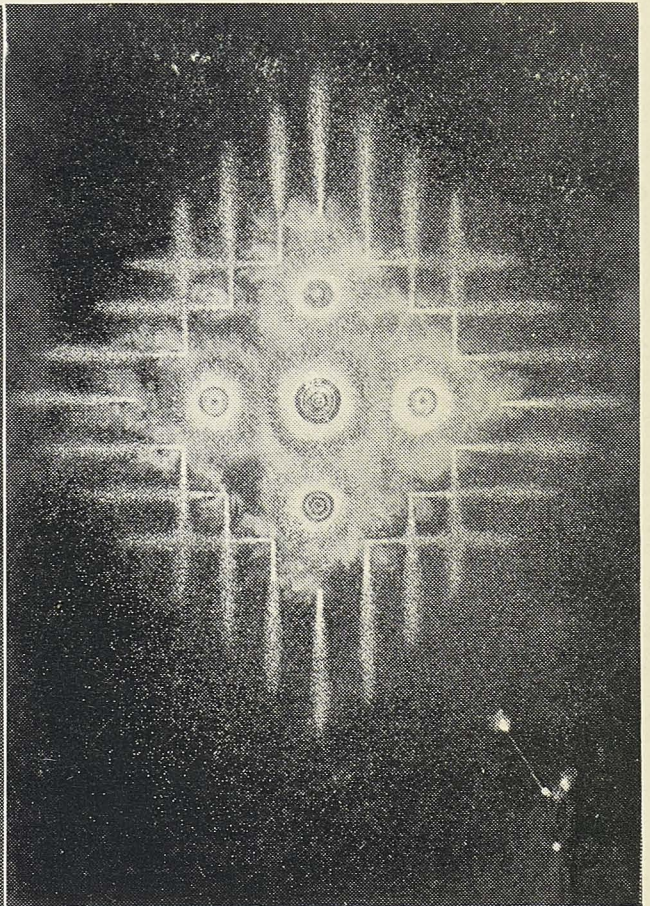
TYPES OF COMPOUND FIREWORKS



Lattice Poles.



Chromatope
(The outer fire forms the Guilloché of Ruggieri.)



Lattice Diamond
(The Feux Croisés of Ruggieri.)

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The drawing is then transferred to the floor with the assistance of the squared lines, and the design followed by nailing on light wood strips or thin rattan cane.

The lines thus indicated are then "pegged," that is, pegs or small wire nails pointed at either end, are driven in at intervals of about four inches. The lances, whose construction has already been described in Chapter IV, have their ends glued and are pushed on to the pegs so that they stand vertically from the framework. The frames are then led up with quickmatch, secured by pins driven into the priming. The match is then pierced with a small awl above the priming, and secured and protected by a strip of paper pasted over it and round the case of the lance. The piece is then ready for hoisting into position and firing.

Formerly, and sometimes now on the Continent, the match was secured by a wire passing through the case near the top, which was twisted over the match.

Ruggieri, under this head, describes a method of illuminating by impregnating wick similar to that used for match-making, with a mixture of sulphur, antimony, and saltpetre. This was wired on to a metal framework. He says it is better than lancework for outlining curves, volutes, etc., as the line is continuous. This difficulty is disposed of in modern English lancework by the closer spacing of lances on curves rendered possible by the smaller lances now used.

He also remarks that this method was rarely used in his time and it is now quite discontinued.

Another device of which he seems proud was a palm tree, the leaves of which were of thin metal from which project spikes upon which was hung cotton impregnated with a composition composed of "vert-de-gris, vitriol blue and sel ammoniac" (copper acetate, copper sulphate and ammonium chloride).

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Immediately before firing the cotton was soaked with alcohol. Actually this composition can hardly be considered pyrotechnic; what takes place is that the alcohol burns, and the flame thus created is coloured with the copper present in the salts. The whole arrangement is too cumbersome and involved for modern use, but at the time of its inception, when colour was practically unknown, no doubt it attracted great admiration.

CHAPTER VI

COMPOUND FIREWORKS (*continued*)

RUGGIERI'S next class (fireworks turning vertically) includes the following :

1. Revolving Suns. These are merely vertical wheels ; he appears to use this term for the more ambitious pieces of this kind.

2. Vertical Wheels. He illustrates a vertical wheel exactly as made to-day under that name. It has, however, been elaborated by the addition of colour cases on the spokes and centre, as rosette and rainbow wheels ; also by the application of saxons to the spokes, as saxon wheels.

He also shows the triangle wheel, consisting of three spokes with grooved ends to receive the cases whose sides form the sides of an equilateral triangle. This has been further developed into the double triangle wheel, with two sets of spokes placed one set behind the other. In all the wheels in this class the cases fire in succession, not as in the case of the sun—simultaneously.

Windmills he illustrates as flat bars pivoted in the centre with three cases at either end fired in succession. There also were three, four, and up to eight-armed windmills of the same kind. The nearest device to these of modern times is the chromatrope, the simplest form of which has two bars with a gerb at either end so set as to revolve them in opposite directions, the front one carrying two saxons. This piece, which is of comparatively simple design, gives an extraordinarily fine effect by the intersections of the various streams of fire.

The chromatrope has been developed and enlarged until for important display work quite elaborate pieces are fired

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under this name. Lancework of geometric form is used on the bars or spokes, and the intersection of these, forming ever-changing geometrical designs, adds greatly to the effect of the intersection of the fire.

This effect is the basis of the Guilloché, a somewhat elaborate piece which falls in Ruggieri's third class. It consisted of six wheels placed one behind the other in pairs of graduated size; the two smallest—which fired first—had six cases, the next eight, and the largest forty-eight, and was twenty feet in diameter.

The next described is the Salamandre, a piece which, on a large scale, is still occasionally fired at the Crystal Palace. It shows a snake in pursuit of a butterfly which it seems to overtake but never quite catches. The mechanism is an endless chain of wooden links running in and out between eight sprocket wheels, arranged in octagon formation. About half the length of the chain is made out and lanced to represent the snake, and a lancework butterfly is situated in the centre of the other half.

Ruggieri claims that his father fired this piece and the guilloché in 1739 at Versailles.

The other pieces mentioned in this section are too elaborate for description in the space available, but are interesting as showing the use of the helix and spiral as applied to wheels and cones, as secondary elements of larger pieces.

The modern designer of pyrotechnic pieces has great advantage over the earlier practitioners in that he has available an infinitely larger range of colour and other composition. It is often possible to get a much-enhanced result with less cases giving more or varied effects as opposed to a larger number of cases of similar effects, which, in an attempt to produce a lavish show of fire, end in confusion.

His fourth division begins with the "Caprice simple";

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this is the modern horizontal wheel. This wheel is similar in arrangement to the vertical above-mentioned, except that its cases are arranged so that the first plays horizontally in the plane of the wheel, the next at an angle downwards, and the third upwards. This succession is repeated with the remaining three cases. In addition, the horizontal wheel has either a mine which is lit from the last case, or Roman candles and mine, and the centre playing upwards. The second form is arranged so that the Romans are fired simultaneously with the fourth case and the mine from the last.

The wheel given by Ruggieri has a gerb in the centre. He explains that Caprice is a generic name applied to all horizontal wheels which vary the direction of the fire when revolving. However, at the present time the name Caprice is only applied to a wheel with three tiers of three cases, each similar in appearance to three single triangle wheels superimposed at distances about equal to their diameter, the grooves in the end of the spokes being so arranged as to vary the direction of the fire. The cases are led up in the following order—one case horizontal, one up, one down, one horizontal, two cases one up and one down, four cases in each direction and one vertical. For a compact piece this is one of the most effective made.

A similar piece is the Furiloni Wheel, which has, however, two tiers of three cases each.

Jones describes a furiloni wheel which is more elaborate, having twenty-five cases. His method of leading would, however, not be so effective as the modern wheels of this type. The cases used for these wheels are charged with a steel mixing formerly known as brilliant fire.

He mentions two other devices—Caprices petans and Caprices des pâtés. The first of these was a modification of the piece formerly used in this country as the balloon wheel. It

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consisted of a solid wheel round which are a series of mines which discharged in succession as each turning case lit. The second was similar but more elaborate, having rockets as well as mines, and was a variation of the rocket wheel.

In his description of the Girandole, he explains that it is composed of two horizontal wheels one above the other. This is the form taken by the rocket wheel as fired in this country, which, as we have seen, was known as the girandole wheel. Ruggieri, however, appears not to have used rockets on his girandole.

The last device he mentions in this class is the Spirali, which consisted of a framework in the form of a cone, round which was wound a spiral of cane fitted with lances.

A very effective piece, not mentioned by Ruggieri, is the revolving fountain ; it consists of a wood centre bored to turn on a vertical spindle. The centre has two spokes fitted with gerbs for turning, and has playing vertically a large gerb and Roman candles. The turning gerbs play tangentially and slightly upwards.

Jones describes a similar device under the name of "illuminated spiral wheel" ; also two other horizontal pieces—the spirali and the plural wheels, which approximate to the furiloni and caprice wheels of the present day.

The spiral and helix are much used in larger devices, and the use of modern lancework and colour has greatly added to their effect.

Ruggieri's next division deals with built-up lancework pieces such as the globe, which it was thought worthy of separate mention in his time, but to-day is included with many devices of this nature too numerous to mention, forming, as they do, a large proportion of the mechanical and other pieces used in display work.

He then deals with tourbillions and table wheels. The



A Display ready for Firing, Dresden, September 1st, 1899. Firework Portraits of the King and Queen of Saxony on the right, Bismarck second from the left.

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latter consisted of a circular table with a central pivot, round which is free to revolve a bar which forms the axle of a wheel, the hub of which runs on the edge of the table. When the wheel is turned, the hub running on the edge of the table moves it forward in a circular path round the pivot. This principle is applied to similar and more elaborate devices. The name *tourbillions*, as before mentioned, is by other writers differently applied.

The section dealing with cut-out and transparent devices is of little interest. These devices were an attempt to give variety from the monotonous repetition of turning cases and gerbs. To-day the use of colour cases, lances, a much-enlarged range of fountain and similar compositions, including aluminium and other brilliant fires, has obviated the employment of effects which cannot be rightly considered as pyrotechnic.

The moving and stationary pieces considered in this and preceding chapters give a good general idea of the firing methods in compound fireworks. As we have already noted, the difference of designs and effects at the present time is infinite, so that it would be impossible in a work of the present size to give anything approaching a complete survey of what has been accomplished. But it is hoped that enough has been said to give the reader some idea of the methods adopted and the lines upon which the modern pyrotechnist works.

CHAPTER VII

FIREWORK COMPOSITIONS

IT may have been remarked in the foregoing chapters that, although the ingredients composing the firework mixtures are given, generally the proportions are not.

The reason for this is two-fold : primarily, as we have seen in the chapter on rockets, the proportion of the ingredients of a firework varies in accordance with its size. So that to give the proportions of the compositions of any one type of firework would often require as many formulæ as there are sizes.

Secondly, and perhaps more importantly, the quality and purity of chemicals as supplied in bulk vary so enormously that a constant series of experiments has to be conducted in order to ascertain what modifications and adjustments are necessary in the formulæ to give the required standard of performance.

It is not meant to suggest that the impurities generally to be found in bulk supplies are necessarily harmful to pyrotechnic results. This is not so ; salts give far better results in their natural or mineral form than do those prepared synthetically. As an example of this saltpetre may be cited. For pyrotechnic purposes the best obtainable is that from Bengal, yet an analysis of this would probably be found to be less pure than that synthetically prepared in Germany. But experiments have shown that samples of the latter, taken from the same cask, but in different parts, produce very distinctly varying results pyrotechnically.

Pyrotechny is an art, chemistry is a science, and although it is impossible to deny that the former is greatly indebted to

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the latter for the supply and production on a commercial scale of chemical ingredients, yet it is possible to overestimate the position of chemistry in the art, or possibly it might be more correct to say that pyrotechny has its own chemistry.

Chemistry without pyrotechnic experience is apt to lead to erroneous conclusions. To take a concrete instance: in an article in a famous encyclopædia, obviously written by a chemist of standing, a portion deals with the use of metal salts in the production of colour; the writer gives copper as producing green, which no doubt it does in the laboratory; in practice, however, copper is used solely for the production of blue.

The question of purity in chemicals used in pyrotechny is a secondary consideration, that is, of course, as long as the adulterants have no adverse effect either as regards the pyrotechnic result or the safety of the worker in manipulation. What is of first importance is its pyrotechnic suitability, that is, it must produce the required result and must be consistent. Unequal results are the bugbear of the firework makers. As we have seen, constant experiments are necessary to keep an even standard, but with irregularly functioning chemicals these would be multiplied to an impossible degree.

The first group of compositions for consideration is that nearest related to gunpowder, in fact, for the purposes of a work on pyrotechny, gunpowder may be considered a particular case of this class.

The governing principle of this group, and one may say of all firework compositions, is the same. For combustion to take place oxygen must be present. When an inflammable article such as a piece of paper is set on fire it takes up oxygen from the air. A pyrotechnic composition, however, is so arranged that one of the ingredients has a supply of oxygen which it is ready to give up; another, or others, are of a kind ready to receive and combine with this oxygen.

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The oxygen-supplying ingredient which is by far the most frequently used is saltpetre, or, as it was formerly called, nitre, known chemically as nitrate of potash.

Saltpetre may be said to be the basis of pyrotechny. There is hardly a formula by any of the writers on pyrotechny up to at least the middle of the nineteenth century which does not contain it.

Gunpowder is composed of saltpetre, sulphur, and charcoal, three chemicals which it will have been gathered from the previous pages play a prominent part in very many of the pyrotechnic compositions. In some compositions their proportion is apparently identical with that of gunpowder, yet they do not form gunpowder as they are not milled, and are consequently not so intimately mixed. Compositions containing these ingredients have frequently an admixture of mealed gunpowder, the function of which is to give additional fierceness when required, as is the case in some rocket mixings.

These chemicals, as we have seen in the previous chapters, are the components of rockets, turning cases, tourbillions, saxons, Roman candle fuse, and many others. When variation was required in fireworks used to give a simple fountain effect the earliest addition was of metal in finely divided particles, as filings, borings, or the now almost obsolete iron sand.

Steel filings were used in what was known as "brilliant fire," a term which has fallen into disuse since the introduction of other metals whose effects eclipsed that of steel. It has also been used where extra effect is wanted, that is, more tail in rockets and tourbillions. It is, however, not much used in the former case to-day, as the presence of steel in a composition which is to be charged on a steel spindle introduces a decided element of risk into the operation.

The introduction of steel and iron was the first use of metals in firework making, probably the next metal to be

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introduced was antimony, either black (sulphide) or regulus. Jones (1765) was already using what he calls crude antimony ; this was probably the black sulphide.

Before the introduction of genuine colour, and while the chemicals which had been adopted for pyrotechny were still very limited in number, attempts were made to obtain either a semblance of colour or some variety in stars and garnitures by the addition of such substances as powdered glass, brass, sawdust, beech raspings, which appear to have functioned as do the iron or steel in the compositions already discussed, except that there would be no coruscation even with the brass. These additions would merely show as red-hot particles in the jet of fire.

Kentish gives two gerb compositions, one of which contains coke grains, and the other porcelain grains, which would apparently produce cognate results ; the use, however, of both these ingredients is now almost if not quite obsolete.

Antimony, on account of its ready combustion, is more completely consumed before leaving the case. In this connection it may be mentioned that care is necessary in a mixture containing steel or iron to avoid too large a proportion of the oxygen-bearing ingredient, for fear of consuming it inside the case.

Another composition producing remarkable coruscations is the old-fashioned " spur fire," which consists of saltpetre, sulphur, and lampblack. This composition requires very careful and experienced mixing, or no effect will be produced, rendering its preparation a very lengthy process.

This difficulty was somewhat overcome during the last century by the addition of orpiment or sulphide of arsenic. Even with this addition, however, its manufacture requires care and patience. It is a curious fact that this composition, unlike most others, has the quality of markedly improving by keeping. How the lampblack produces this unique effect, or

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why its effect should be so different from that produced by any other form of carbon, has not been satisfactorily explained.

The compositions we have been considering fall into one of two classes, namely, those to produce force and those to produce sparks. These two classes, with one other, namely, that of colour, may be said to include all the modern recreative firework compositions. Up to the end of the eighteenth century the ingredients used in the production of the compositions of these three classes were very few in number. A considerably larger number went to supply the ingredients for a fourth class now almost extinct, these might be called the flame-producing class. The principle on which these compositions were designed was, as it were, to overload a mixture of saltpetre and sulphur with combustible material; this latter took the form of gums, resins, or fats, the object being to produce a reddish or golden coloured flame. The early writers give formulæ for variously coloured stars and fires, which must have required considerable effort on the part of the observer for identification. These belonged to the flame class.

Frézier, with more perception than most of the others, realised the shortcomings of such compositions, merely designating them greenish (*verdâtre*), yellowish, reddish, and russet. The only colour which he professes to produce distinct is blue, which he obtained with pure sulphur.

Progress from the earliest times of pyrotechny up to the first quarter of the nineteenth century was very gradual and very slight. The chemicals used by Bate and Babington in their actual pyrotechnic compositions were as follows:—Gunpowder and its constituents, camphor, pitch, resin, orpiment, linseed oil, both pure and boiled, oil of spike (*spica lavandula*), oil of petre (rock oil), an oil known either as benedict or tile, varnish (probably amber), iron scales, and aqua vitæ (spirits of wine).

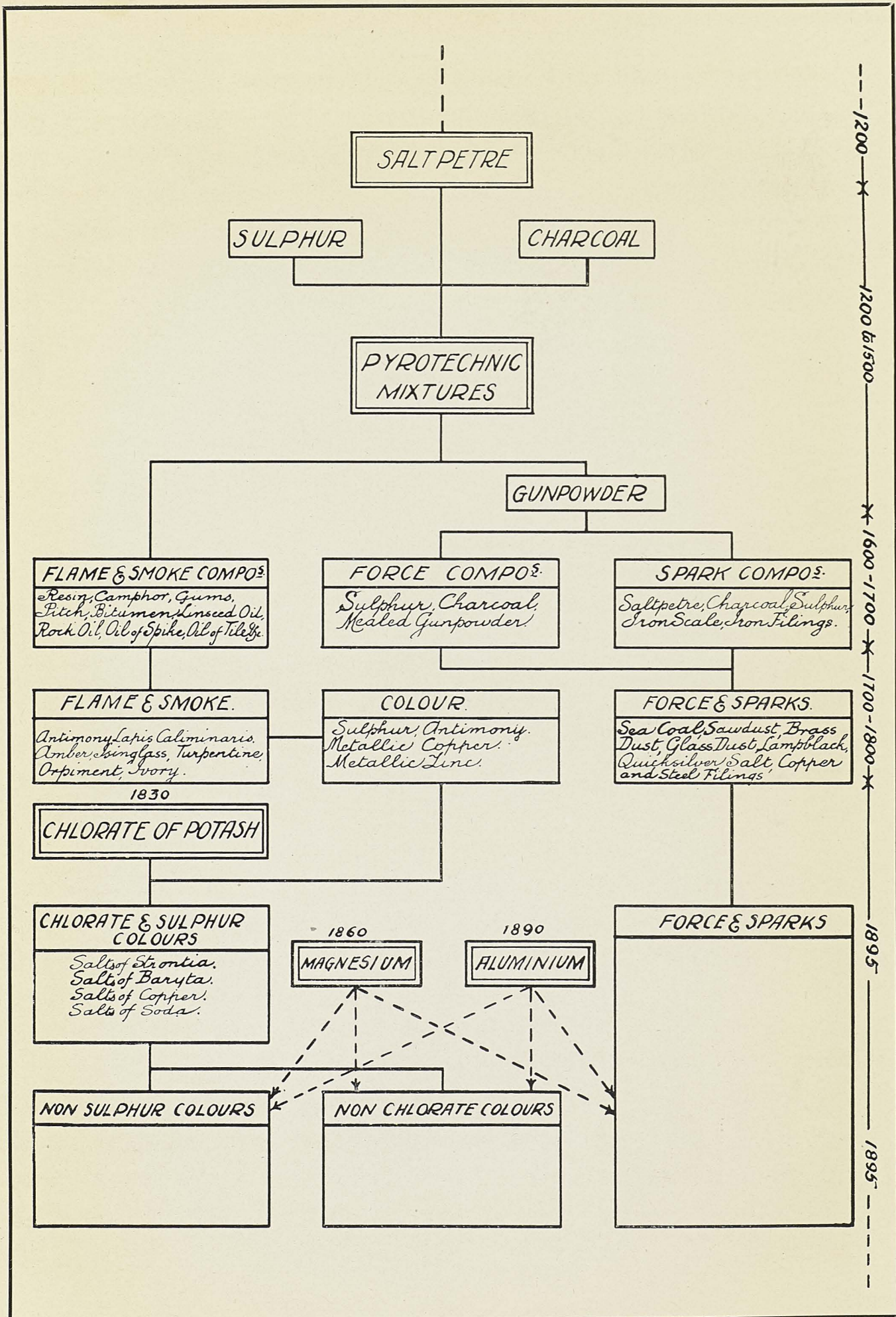


Diagram illustrating the evolution of Pyrotechnic Composition.

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Bate extends this list considerably by the ingredients of a series of compositions which he has evidently taken from some alchemistic work. These compositions are all either designed to burn under water or to ignite spontaneously in water, and fall somewhat outside the bounds of our subject. Frézier also includes these, evidently from the same source.

Bate also refers to a liquid, the recipe for which was probably taken from the same work.

“Aqua ardens.” The following are his directions for preparing it : “Take old red wine, put it into a glassed vessell, and put into it of orpiment one pound, quicke sulphur halfe a pound, quicke lime a quarter of a pound ; mingle them very well, and afterwards distill them in a rosewater still ; a cloth being wet in this water will burne like a candle and will not be quenched with water.”

It is difficult to see what he obtained by this process differing from spirits of wine. The quicklime would serve to dehydrate the wine, and probably no part of the orpiment or sulphur would be taken over in the distillation.

Rather over a century later we find Frézier and Jones have made some additions to the ingredients of pyrotechny, the most notable innovations being the use of iron filings (not to be confused with the iron scales of Bate, which were probably hammerslag, the magnetic oxide of iron), steel filings and pulverised cast-iron. Beyond these, and the spark-producing agent already mentioned, the other additions are of small importance, the most notable being lapis calimnaris, or the mineral carbonate of zinc, which however was not used as are metal salts to-day, that is, for the production of colour.

Jones's book, written some years after that of Frézier, shows little advance from the latter as far as pyrotechnic results are concerned. What he has done, however, is to eliminate what might be called the alchemistic, or one

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might almost say magic element with which it is pervaded.

In attempting to classify the compositions in Frézier's book, one is staggered by the grotesque character of many of them and by the extraordinary variations in the proportion of their ingredients, even amongst compositions designed for a similar effect.

Presumably with the intention of impressing his readers with the wonders of the science, he added ingredient after ingredient, which, if they did actually no harm to the composition, certainly in no degree assisted its functioning.

In what he calls a simple star there are eleven ingredients, of which, in fact, four only are essential.

Further, beyond the multiplication of unnecessary ingredients in individual compositions, there is often their incompatibility and innate unsuitability for the purpose. Such components as ink, onion juice, and the drainings of a dung-heap suggest so strangely the formulæ of the alchemists that one almost expects to come across "the hair of a Barbary ape," or similar absurdity.

Ruggieri, who may be considered as the last of the old school, is the first author to deal with the subject in such a way as to convince the professional reader of the practical knowledge of the subject.

His additions to the list of ingredients are not many, but they are genuine. He is the first writer to make use of metals or their salts in the production of colour ; he includes among his chemicals metallic copper and zinc, also the acetate and sulphate of copper, and chloride of ammonium. The notable advance in his colour compositions, besides the use of metal salts for that purpose, is the introduction of a chloride, which has the effect of improving the colour by assisting in the volatilisation of the metal. For this purpose he used sal-ammoniac, the use of which has now been almost discontinued on account of its hygroscopic nature, notwithstanding that its

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base of ammonium is very useful in compositions containing copper. Its place is now generally taken by calomel ; in such compositions chloride of sodium had been used for many years, but not as a chlorine carrier. Ruggieri appears to have been the first to produce colour on anything approaching modern lines, and although he did not progress greatly, what he did achieve was undoubtedly a marked advance in the art.

His account of the invention of this composition is interesting. He says that he was told by a returned traveller from Russia of a set piece representing a palm tree, " the colour of which rivalled nature." This piece he set out to imitate, which he did, at any rate to his own satisfaction. The result he obtained would undoubtedly give a good colour, if the method of firing was very clumsy. He remarks that he does not know if his method was as that adopted in Russia, and later of the " merit if not of discovering a new fire at least to have imitated or rather to have rediscovered it." It appears, therefore, that there may be some doubt as to the originality or priority of Ruggieri's achievement in this direction, but he must be credited at least with independently arriving at the result. Indeed it is more than probable that the piece seen in Russia was quite different, a transparency or illumination, either imported or copied from the work of Eastern pyrotechnists, and that the whole credit of introducing colour into the art belongs to Ruggieri and to him only.

He mentions that he puts it on record with the object of " thus preventing writers from attributing it to the Chinese, the Medes, or Arabs, as is the custom in Europe, and above all in France, where more than elsewhere there is a mania for enriching foreigners with our merits and to rob ourselves of the birthrights of genius."

CHAPTER VIII

MODERN FIREWORK COMPOSITIONS

RUGGIERI may be regarded as the last of the ancients. It is true that his book shows a marked advance on anything that had gone before, also that he appears to have been one of the first, if not actually the first, to introduce the use of metal salts in the production of colour. But he makes no reference to the use of chlorate of potash, and it is the introduction of this salt into pyrotechny which marks the commencement of the modern epoch of the art.

This earliest use of chlorate, or as it was then called, oxymuriate or hyperoxymuriate of potash, appears to have been soon after its discovery in 1786 by Berthollet. Samuel Parkes, in a work on chemistry written in 1811, says: "The shocking death of two individuals in October, 1788, and the burns others have suffered by it, render it feared by chemists in general," that is in conjunction with sulphur and charcoal.

He later remarks that notwithstanding this accident "the French have since — actually employed in one of their campaigns gunpowder made with oxymuriate of potash instead of saltpetre," and adds that a Scotch clergyman had taken out a patent for the use of a powder containing chlorate of potash to be fired by percussion.

This patent, granted in 1807, is the first for the percussion system in firearms.

The use, however, of chlorate of potash in propellant compositions presents no very great advance in pyrotechny, however revolutionary may have been the introduction of the percussion system into the manufacture of firearms.

It is its use in the production of colour that marks the modern epoch.

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The exact date of this innovation appears to be about 1830.

A Belgian lieutenant of artillery, Hippert by name, published in 1836 a translation of a work by Captain Moritz Meyer, of the Prussian Artillery, on the application of chemistry to artifices of war.

In a chapter devoted to coloured fires he gives several formulæ containing chlorate of potash. Although this appears to be the first published notice of its use, it seems likely that by the time the book was published that it was fairly well established.

Meyer concludes his remarks on coloured composition by saying that the English at that time made use of coloured rockets for signalling at sea, and had succeeded in producing ten different shades, "which are quite sufficient for the purpose of signalling particular pieces of information."

This seems rather to indicate that the elaboration if not the first introduction of chlorate of potash into pyrotechny may be attributed to this country.

His mention of ten distinguishable tints, however, is somewhat optimistic. During the late war it was found that to avoid any chance of a mistake in code signals only three colours could be used for long-distance signalling, namely, red, green, and white.

It is curious that Meyer makes a mistake over the first composition he mentions. He describes a light composition of chlorate of potash and sugar, which he says burns with a red light. In fact, however, the light so produced is a bluish white, similar to the so-called blue shipping light.

The directions he gives for the preparation of other colours are as follows :

"A powder which burns with a green flame is obtained by the addition of nitrate of baryta to chlorate of potash, nitrate of copper, acetate of copper.

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“ A white flame is made by the addition of sulphide of antimony, sulphide of arsenic, camphor.

“ Red by the mixture of lampblack, coal, bone ash, mineral oxide of iron, nitrate of strontia, pumice stone, mica, oxide of cobalt.

“ Blue with ivory, bismuth, alum, zinc, copper sulphate purified of its sea water (*sic*).

“ Yellow by amber, carbonate of soda, sulphate of soda, cinnabar.

“ It is necessary in order to make the colours come out well to animate the combustion by adding chlorate of potash.”

These formulæ, if somewhat incoherent, and clearly showing a want of experimental verification, indicate a real advance in pyrotechnic chemistry, not only by the addition of chlorate of potash, but by the multiplication of the number of metal salts used.

At the same time it is evident that the old alchemistic ideas were not entirely extinct by the use of such ingredients as ivory, mica, and pumice stone.

However, there can be no doubt that from the third decade of the nineteenth century dates the modern era of the pyrotechnic art. From this date onward chemical ingredients, metals and their salts as they were provided by the commercial chemist were eagerly taken and tested by the pyrotechnist, and adopted or rejected on their merits. And from this date begins the rapid elimination of useless additions.

Of those compositions given above the following salts are at present in use : nitrate of baryta, sulphide of antimony, sulphide of arsenic, nitrate of strontia, copper sulphate, carbonate of soda, and chlorate of potash.

Zinc, alum, lampblack, and oxide of iron are also used, but not for the purpose indicated.

Nitrate of copper and sulphate of soda would both be

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valuable ingredients, but their unstable nature prevents their use under modern conditions.

Meyer also describes the use of salts to tint an alcohol flame, which is merely an elaboration of Ruggieri's palm tree and of little interest at the present time.

The next name prominent in pyrotechny is that of F. M. Chertier, who published in 1854 his "*Nouvelles recherches sur les feux d'artifice*," after having published a pamphlet on the subject about twenty-five years previously.

In this work Chertier devotes most of his attention to the subject of colour, and although new ingredients have been introduced which were either unknown or were not then available on account of expense or other causes, since the time of his writing, yet there can be no doubt that Chertier stands alone in the literature of pyrotechny and as a pioneer of the modern development of the art.

Tessier, in the introduction to his "*Treatise on Coloured Fires*," published in 1859, whilst paying tribute to Chertier's work, regrets that he only possessed "quite superficial notions of chemistry." Here speaks the chemist. The writer recently asked a pyrotechnic chemist of many years' experience, whose knowledge of pyrotechnic chemistry is probably second to none, his opinion of Tessier's book, and received this answer. "Tessier's book contains too much chemical theory and too little pyrotechnic practice." There speaks the pyrotechnist.

The writer, as he has before remarked, has no wish to belittle the value of the chemist's work in relation to pyrotechny, but a knowledge of chemistry is not the most important attribute of the successful pyrotechnist.

As in other arts so in pyrotechny, experience and natural aptitude are the first essentials.

Chertier may have had little knowledge of chemistry, but

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in spite of or perhaps because of his lack of chemical knowledge, he was able to produce a work which, from the point of view of the practical pyrotechnist, has never been equalled.

His researches were conducted by practical experiments; he had one end in view, namely, pyrotechnic effect, and by exhaustive trials of the materials obtainable, unbiased by theoretical consideration, he succeeded in advancing the art to a stage undreamed of a few years previously. It is true that many of his formulæ are not in use to-day, in this country that is, on account of the danger of using sulphur or sulphur compounds in conjunction with chlorate of potash; but there can be no doubt that his writings and research work laid the foundation of modern pyrotechnic practice.

Once the theory of colour production was established, that is to say the volatilisation of a metal salt in a hotly burning composition, it was a matter of less difficulty to either eliminate the sulphur, which was present chiefly as a burnable, or to replace it.

This prohibition, as we have seen, took place in 1894, under Order in Council 15, and affected the production of coloured fireworks far less than might have been anticipated. During the period between the introduction of chlorate of potash and the Order in question, the development of commercial chemistry had increased greatly the number of chemicals available in pyrotechny, so that in some few cases it was found possible to replace the chlorate.

In addition, moreover, most of the leading makers, anticipating some form of restriction on this admixture, had been for some time previously seeking substitute colour formulæ, and although it may be said by some that colours were obtained by the use of chlorate and sulphur which have not been equalled by subsequent formulæ, yet most have not only been equalled but improved upon, and the small minority

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remaining are an insignificant price to pay for the security and safety gained in manufacture.

Between the publication of Chertier's book in 1856 (nearly thirty years later than his first pamphlet) and the close of the century, several works on pyrotechny made their appearance, several by Frenchmen : Tessier, 1859, " *Traité Pratique des Feux colorés*," two works in the Roret encyclopædia series, " *Pyrotechnie Civile* " and " *Pyrotechnie Militaire*," published 1865, and in 1882, " *Traité pratique des Feux d'Artifice*," by Denisse.

The English works of any value during this period were : " *Pyrotechny*," by Practicus, Brown's " *Practical Firework Making*," and " *The Pyrotechnist's Treasury*," by Kentish, 1878. Hutstein and Websky's " *Art of Firework Making*," published at Leipzig in 1878, a book published under the same title by Oscar Frey about 1885, and " *A Theoretical and Practical Treatise of Civil Pyrotechny*," by Antoni, published at Trieste in 1893, together with some works on military pyrotechny published both in Europe and the United States, complete the list.

Some of the military works are of considerable value, but are chiefly directed to the study of rockets and signals ; some, however, are in the same category as " *The Artillerist's Manual and British Soldier's Compendium*," by Captain F. A. Griffiths, R.A., published in 1852. The section dealing with fireworks in this work might almost be taken as an attempt to be humorous on the subject. The author quotes in all seriousness formulæ dating from the days of Bate and Babington, and knows so little of his subject that he gives instructions for making the same firework under different names under the impression that they are distinct units, the information being obviously pillaged from earlier writers. Generally a study of the above-mentioned works indicates

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that the tendency in pyrotechnic compositions has been in the direction of simplification. During the eighteenth century the useless ingredients had been in a great measure eliminated. The "burnables" had been reduced from a long list of alchemistic survivals to a mere half-dozen or so.

Gums had been reduced practically to shellac alone (the use of gum arabic as an adhesive is quite distinct), carbons to lampblack and charcoal, and these with sulphur and sulphides of antimony and arsenic practically completed the list.

Of the metals the use of pure zinc, copper, and brass has been discontinued, and the two almost revolutionary additions of magnesium and aluminium made, the former about 1865 and the latter in 1894.

The date of the introduction of these metals marks almost as great advances in the art as did the introduction of chlorate of potash. Not only are they used as spark-producing metals in the same way as are steel and iron, but they are also used as "burnables," that is, they are consumed inside the case; and many of the present-day firework compositions owe their brilliance to one or other of these metals.

It is, however, in colour compositions that the tendency towards simplification is most strongly exhibited. In Kentish's book colour compositions containing as many as seven or eight ingredients are common, whereas to-day formulæ containing over four are the exception rather than the rule.

The reason for this complexity is not easy to follow, but it may have been in some measure due to the difficulty of obtaining sufficiently finely ground chemicals before the days of machine grinding; in some cases it was found that by melting two of the ingredients together and allowing the mass to cool they could be ground with greater ease. Chertier went so far as to melt shellac and salt together, grind them and



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[Frontispiece

Display at the Tercentenary Fetes, Quebec, July 23rd, 1908. The largest display ever fired in the Western Hemisphere. From a drawing by C. M. Padday.

022
B78



Roman Candles. This untouched photograph illustrates the extraordinary brilliance of aluminium compositions. Each "plume" (200 ft. high) is produced by a single star about $\frac{3}{4}$ in. diameter and $\frac{3}{4}$ in. long. Each line is a microscopic particle of aluminium.

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remove the salt by dissolving in water. Also by adding a finely ground chemical of similar action to one only coarsely ground a better result was obtained.

Whatever may have been the reason, there can be no doubt that, except for secondary shades, the fewer the chemicals used the more brilliant will be the resulting fire.

CHAPTER IX

MILITARY PYROTECHNY

THE use of pyrotechnic mixtures for military purposes is the basis of artillery, and one might almost say the foundation of chemistry. Before the age of the alchemist men were at work endeavouring to produce some weapon which would give them an advantage over their enemies. Of the natural phenomena none made so strong an appeal as fire, which from earliest times had been a mysterious and therefore terrible element.

The early use of fire or pyrotechnic mixtures gave the users so decided an advantage over their enemies that their use was chronicled by historians of the day either on the side of the victors as a pæan of praise for their invincible weapon, or as an excuse for defeat on the side of the vanquished.

Such reports are necessarily vague and exaggerated, vague because the writer had no technical knowledge of the subject, and the users naturally wished for secrecy and exaggerated because exaggeration increased the value of the weapon.

It is from such reports that we obtain our information about Greek fire and similar compositions, and when one considers that the translations were generally biased, in most cases unintentionally but still biased, in favour of reading into passages referring to fire or projectiles an early reference to gunpowder, guns or some unknown pyrotechnic effect, it is obvious that all information so gained must be accepted with a considerable amount of reserve.

The translators, too, in many cases were men of no technical knowledge, which made them even more prone to fall into errors which would be avoided by the expert.

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Of the mass of writing dealing with the subject, the work of two writers stands out prominently—the late Mr. Oscar Guttman in his “History of Explosives,” and Col. H. W. L. Hume in his “Origin of Artillery,” whose observations cover the field of information on the subject, although approaching from slightly different angles.

Neither, however, gives an exact explanation satisfactorily covering the projection of Greek or sea fire. Col. Hume, rejecting earlier theories, goes somewhat to the other extreme : he denies the knowledge of saltpetre before the twelfth century, but attempts to explain the phenomenon by the use of phosphide of calcium.

He premises four conditions to be filled by the weapon or apparatus. These conditions are fulfilled by the explanation already briefly touched upon on page 15, and the writer is convinced that this simple although apparently little known phenomenon is the true explanation of the terrible, mysterious Greek or sea fire.

If a mixture of saltpetre, pitch, and sulphur is charged into a long tube sufficiently strong and ignited it will burn, giving off dense smoke, for a short time, when it appears to choke momentarily. This choking is followed by a more or less violent outburst, which may be likened to a “cough,” projecting a burning mass of composition to a considerable distance; the action is repeated with surprising regularity during the burning of the whole of the composition throughout the length of the tube, and will, the writer is confident, satisfy any unbiased observer that here is the true explanation of the phenomenon.

Let us see how the requirements mentioned by Col. Hume are fulfilled. The first, “It was a wet fire,” *i.e.*, its action necessarily connected in some way with water or the sea, and as a matter of fact it was used at sea with great success

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on many occasions. May not a "wet fire" be a way of saying "a molten, viscous mass of fire"? The masses would float, and although some might become extinguished, some would probably burn on the surface of the water; also its use at sea would, with a range up to a hundred yards, be quite as easy as on land.

Secondly, "Its composition was such as could be kept secret at Constantinople." If, as Col. Hume says, saltpetre as such was unknown at the time, it was only as a separate kind of salt. It was undoubtedly known, but not distinguished from sea salt or nitrate of soda. Would not this fact render the concealment of the ingredients used more easy?

Thirdly, "It burned with much noise and smoke." Allowing for some slight exaggeration the first condition is fulfilled, as undoubtedly is the latter.

Fourthly, "It was necessarily connected in some way with syphons." As Col. Hume points out, there is ambiguity between the word syphon and tube, and if the latter word meets the facts it seems the more likely rendering.

The writer saw this effect produced during experiments with smoke-producing compositions, and it is probable that the mixture in question was not in the most effective proportions, but so striking was the result that there is little doubt that experiments on such lines would produce a terrible and effective weapon under the conditions of warfare then in existence.

The "Dictionnaire Mobilier Français" gives a diagram of a weapon of a somewhat similar nature stated to have been used by the Arabs in the fifteenth century. The illustration shows what is virtually a Roman candle, and appears plausible until one considers the facts. What is most probable is that the weapon, which was of an incendiary nature, was similar to that described above, which fulfils the requirements

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of the description without assuming a knowledge of compositions which at the time did not exist.

From the period of Greek fire onward military and recreative pyrotechny appear to have marched side by side.

As we have seen, the progress in the latter branch was extremely slow, so with the former, and it was not until the introduction of modern or comparatively modern methods that real progress commenced.

With the progress came divergence, the introduction of the rifled bore in artillery, and of nitro compounds and high explosives whose dynamic force exceeds many times that of gunpowder, which however useful they might be to the artillerist, were of little value to the recreative pyrotechnist. It was not until the great war that the resources of pyrotechny were fully realised and utilised by the military. It is curious to note that just as the tactics and methods of warfare eventually adopted—although on an unprecedentedly large scale—were in a great measure those of centuries before, so military pyrotechny returned to ideas just as antiquated. With the advantages of modern science, and by the assistance of knowledge gained in the development of recreative pyrotechny, the progress made in a month or so in military pyrotechny during the war may, without exaggerating, be said to have exceeded that of previous centuries.

Speaking generally, the use of pyrotechny in warfare, or indeed any science, has two objectives, the first to destroy or embarrass the troops of the enemy, and secondly, to assist one's own.

Until the late war it was the first of these which received by far the greater attention, and it is but natural that the introduction of the modern methods mentioned above should have provided means which left pyrotechnics far behind. In the second division, however, pyrotechny triumphed.

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Of the offensive type the earliest use of pyrotechny was the incendiary. Greek fire, wild fire, and similar compositions have been used from time immemorial to set fire to enemies' works or ships or to injure his personnel. And just as incendiary compositions antedated the propellant, so the incendiary shell appears to have preceded the explosive.

Incendiary projectiles of the past were known as carcasses ; the earliest form appears to have been a canvas bag or container pitched over on the outside and bound with iron hoops, which, from their likeness to the ribs of a corpse—according to "Chambers' Encyclopædia" (1741)—suggested the name.

The fireball was similarly constructed and designed for hand projection, bearing the same relation to the carcass as does the grenade to the bomb.

The composition in most incendiary missiles consisted of a mixture of saltpetre, sulphur, and pitch, with or without the addition of mealed gunpowder.

The most recent form of carcass was a spherical shell of iron, having three vents, and filled with incendiary composition. This projectile became obsolete in the Service at the end of the last century.

Another form of pyrotechnic projectile was that designed to give out smoke, either with the idea of rendering the atmosphere of works or casemates unbearable to the defenders (a principle revived in the late war by the use of poison gas), or to hinder them by obscuring their vision either by firing a smoke cloud in their (the enemy's) works, or so placed as to hide one's own troops.

It is open to discussion if the use of smoke is not indeed of greater antiquity than that of incendiary missiles, but it is probable that its origin was its production by the combustion of grass or similar material, and not with pyrotechnic composition.

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Read's "Weekly Journal" of October 25th, 1760, in an account of a review in Hyde Park, mentions as the concluding item of the manœuvres, that "pieces of a new construction, of a globular form, were set on fire, which occasioned such a smoke as to render all persons within a considerable distance entirely invisible, and thereby the better in time of action to secure a retreat." There can be little doubt that this is one of the first demonstrations, at any rate in this country, of the use of smoke balls.

The Chinese made use of both projectiles many centuries ago, and the smoke—or stink-pot—was in use by them until comparatively recently.

Smoke balls from 4½th inches up to 13 inches calibre were included in the official list of projectiles for smooth-bore guns until about 1873, when with ground light balls they became obsolete. The latter, as their name suggests, were intended to be burnt on the ground and light up enemy working parties, etc. This also was the object of the parachute light-ball, which was fitted with a time fuse and an opening charge; upon opening, a light was ignited suspended from a parachute. This method appears to have been invented in Denmark in 1820, and they were used in Austria the following year.

Another class of war store which naturally suggests itself is that used to give light for the purpose of signalling. The light is either burnt on the ground as a hand light or fitted to a rocket. Fireworks for this purpose have been in use from earliest times, being the logical development of the signal beacon, but it was not until the introduction of genuine colour—that is to say, colour distinguishable at a long distance—that they reached their full standard of utility.

It is, however, the rocket which has received most attention for military purposes, and certainly with good reason. Here

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was a projectile which, in the days of smooth-bore ordnance, had a good range and required no heavy gun or transport. Moreover, it formed its own time fuse. Congreve wrote: "Rockets are ammunition without ordnance, the soul of artillery without the body." Many methods of fitting up rockets for warlike purposes have been evolved, invented, and re-invented, most of which for practical purposes were useless.

It is the military use of the rocket, however, which presents the most interesting study in military pyrotechny.

There are several early references to what is supposed to be the use of rockets in warfare. The Paduans are stated to have burned the town of Mestre with these projectiles.

Orleans used rockets in its defence in 1429, and Dunois fired them in 1449, when besieging the town of Pont-Andemer. In 1452 they were used against Bordeaux, and the following year at Gand.

Rockets were employed in 1586 for lighting purposes and as projectiles against cavalry. The description seems to indicate a method of fitting up to produce a similar effect to a shrapnel shell.

Hanselet, writing in 1630, refers to rockets with grenades attached. Casimir Siemienowitz, Lieut.-General of the Ordnance to the King of Poland, published in 1650 his "Great Art of Artillery," which contains a treatise on fireworks both for civil and military purposes. He refers to a work on the military use of fireworks written ninety years before, and speaks of rockets up to 100 lbs. and describes their construction.

A French work published in 1561, entitled "Treatise upon several kinds of War-Fireworks," suggests a rocket case of varnished leather.

It is on record that in 1688 trials were made in Berlin

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with rockets of 50 lbs. and 120 lbs., which carried a bomb weighing 16 lbs. The composition was nine parts saltpetre, four parts sulphur, and three parts charcoal. The case is stated to have been of wood covered with linen.

Hyder Ali is credited with making considerable use of rockets against our troops in India ; he is said to have had a corps of 1,200 " rocketers " in 1788, whilst later on, his son, Tippoo Sahib, employed as many as 5,000, and Captain Moritz Myer, writing in 1836, ascribes to experience of these weapons so gained the efforts made in England to bring them to perfection.

He also describes the Indian rocket as " an iron envelope about 8 inches long and $1\frac{1}{2}$ inches in diameter, with sharp points at the top. The stick of bamboo 8 or 10 feet long, but sometimes consisting of an iron rod. They were hand-thrown by the rocketers, and did much damage to the cavalry."

This description, which, to say the least, is unconvincing, would seem rather to refer to some other pyrotechnic missile.

Whatever may have been the cause, there was undoubtedly great interest in the subject of rockets during the first half of the nineteenth century. Sir William Congreve is perhaps best known in connection with the work of this period. His efforts, however, were rather directed to the development of existing ideas than to invention.

In 1804, after experiments at the Royal Laboratory, Woolwich, a flotilla of boats was fitted out under his direction for the purpose of bombarding Boulogne Harbour with incendiary rockets from frames fixed on the decks. The first attempt ended in a fiasco owing to heavy weather, but the following year better results were obtained, although the rockets were deflected by the wind and did more damage in the town than in the harbour.

In 1807 Congreve personally superintended their use at

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Copenhagen with even better effect, and they were again used in the Walcheren Expedition and in an attack on the island of Aix.

These rockets were all of an incendiary nature, with paper cases, and fired at an elevation of 55 degrees. Myer gives the proportion of the composition as 62.44 saltpetre, 23.18 charcoal, 14.38 sulphur. This writer gives Congreve's rockets little credit for efficiency, but admits that they "attracted great attention and were regarded as formidable." He remarks that at the siege of Flessingen "the rockets acted so badly that the English themselves said that they did more harm to the battery than the besieged town." He also states that as a result of finding an "unburnt specimen" in the town after the bombardment of Copenhagen trials were conducted by Captain Schuhmacher, although how an unburnt rocket could reach the town is not clear; possibly he means from a reconstruction of the remains collected.

These trials seem to have been successful, and in 1808 a rocket brigade was formed.

In 1809 Admiral Cochrane used rockets upon the town of Callao, in 1810 they were used against Cadiz, and in 1813 in the battle of Leipsic, where the commanding officer, Captain Bogue, was killed, and at the siege of Dantzic. It is interesting to note that during that year they were used for propaganda purposes. At the siege of Glogau proclamations, etc., were printed on thin paper and fastened to the sticks with light thread. Rockets were used with effect at Waterloo, the rocket detachment being directed by Sergeant Dunnet.

In 1813 Colonel Augustin, of the Austrian army, saw the English rocket batteries in action and trials of Congreve rockets in London, and the following year visited Copenhagen, where by arrangement between the two Powers he was instructed by Schuhmacher in his method of rocket construction.

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The Austrian Government as a result established shortly afterwards an extensive factory at Weinerisch-Neustadt for the manufacture of war rockets.

Much work and ingenuity was expended about this time in seeking to eliminate the necessity of the rocket stick. Congreve is credited with introducing fins similar in action to the feathers on an arrow ; this, however, had been done nearly one hundred years previously, and Frézier illustrates the method in his treatise.

A Mr. Heath, of Boston, is credited with having reached a range of two and a half miles with a five-pound rocket of this type.

Garnier in 1813 proposed to avoid the alteration in position of the centre of gravity by using a wire or chain with a weight at the end fastened to the centre of the rocket and hanging vertically. From Ruggieri's book it would appear that this idea had often been tried previously.

However, the most successful series of inventions were those based on the principle of the rifle, that to give the rocket a rotary motion in its passage through the air.

In 1815 successful trials were made in America with rockets of the rotary type, rotation being imparted by means of holes bored through the case into the composition in an oblique direction.

Congreve established a factory at Bow for the manufacture of rockets for the East India Company, and Captain Parlby, of the Bengal Artillery, manufactured similar rockets, both being made to rotate, probably on similar lines to the American model. The "Calcutta Journal" of the period contains a discussion of the rival merits of Congreve's and Parlby's rockets.

Hale patented a rocket constructed on similar lines as late as 1844, the holes at the side of the case being nearly tangential. He also gave his name to a service rocket—Hale's

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24 pr. and 9 pr. These were constructed of iron with a wooden head, fitted metal plug at the base with three vents, a tail piece or flange continuing from the base so as to enclose half the periphery of each jet. This arrangement imparts a rotary motion to the rocket.

In 1853 Macintosh patented a method of rotating the tube from which the rocket was fired so as to give an initial rotary movement before the flight commences.

The following year Fitzmaurice patented the idea of causing rotation by a screw-shaped head, and Court a method by which the fire impinged on surfaces inclined to the axis of the rocket.

In 1826 Congreve patented a method of fixing two or more rockets together so that the heading of one ignited the next and so obtained a longer time of burning ; this method is, however, again anticipated in Frézier's book.

About this time all the leading Powers in Europe were manufacturing rockets for war purposes, factories for their manufacture being established at Warsaw, Turin, Toulon, and Metz. The Russians used them at this period in their war with Turkey, firing them in salvoes of nine.

In 1831 a series of trials were made by the Swiss military authorities of 6 lb. rockets fired from a 6 ft. tube, when a range of from 18-1900 yards was obtained, and three hits registered out of five were made at 1,100 yards.

Although great interest was aroused by the rocket for war purposes, it quickly subsided, and it is now practically only used for signalling and line-carrying purposes.

William Bourne, who describes himself as a "poor gunner," the first to produce an original book on artillery in this country, as distinct from translation of continental works, makes the following observations on military pyrotechnics :
" Divers gunners and other men have devised sundry sorts of

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fireworks for the annoyance of their enemies, yet as far as I have ever seen or heard, I never knew any good service done by it, either by sea or land, but only by powder, and that has done great service for that the force of it is so mighty and cometh with such a terror. But for their other fireworks it is rather meet to be used in the time of pleasure in the night rather than for any service."

CHAPTER X

MILITARY PYROTECHNY IN THE GREAT WAR

THE outbreak of the great war, whatever may have been the case as regards other branches, found the Service badly equipped pyrotechnically. The great and almost frantic interest taken in military pyrotechny during the first half of the nineteenth century had died away. Gradually the pyrotechnic stores included in the official schedule had been reduced until in 1914 a few rockets—mostly signal—lights for signalling and illumination, Very pistol cartridges for signalling purposes, with single stars of various colours, and incendiary and light stars for shells constituted the entire list.

The cause of this neglect of the art of pyrotechny for war-like purposes was not difficult to understand. Rifled barrels, breech-loading, and quick-firing ordnance had entirely destroyed interest in the rocket as a projectile. The telephone and telegraph had almost entirely superseded older methods of signalling, and so with most of the pyrotechnic contrivances which, less than a century before, had been thought to be indispensable.

As events proved, this abandonment of old ideas was premature. Although every thinking man in the country realised that war was some day inevitable, no one, or at least very few, realised the nature of the struggle. The development of land war into what were practically siege operations on a gigantic scale; the nature of sea warfare with the new factors, the submarine, seaplane and wireless; the extent and ferocity of aerial warfare—all were unforeseen. Yet each of these called for new inventions, new methods of destruction,

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new methods of protection and communication, and in many cases the resuscitation of old ideas long since abandoned.

And as fire has for all time been associated with the sword, it is small wonder that pyrotechny played no inconspicuous part in the struggle.

As has always been the case, and no doubt always will be, the outbreak of hostilities was the signal for an epidemic of inventions. Men who had never before interested themselves either in war, or in that particular department of science to which their ideas belong, and in spite of or perhaps because of an entire ignorance of the subject, inundated the authorities with so-called inventions which were so much waste of time to all concerned.

In this connection it is interesting to turn to a volume of "Abridgements of Specifications relating to Fire-arms and Other Weapons," published by the Patent Office in 1859. The preface contains the following remarks : " It is worthy of notice that a very large proportion of the so-called inventions of the present day are, in fact, old contrivances, sometimes modified and adapted to modern requirements, but very often identical with what has been tried and abandoned as useless long ago. From the year 1617 down to the end of the year 1852, not more than about 300 patents were granted for inventions relating to fire-arms. When the war with Russia broke out the Patent Office was inundated with applications for Letters Patent for similar inventions, and about 600 have since been actually granted. Of these it may be safely said that five-sixths of the applications related to old contrivances which have been patented over and over again."

Many of these inventions recall a story of the Duke of Wellington, who was examining a steam rocket invented and patented by a Jacob Perkins in 1824. This device consisted of an iron case with a stick like that of a rocket. The case was

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filled with water and had a fusible metal plug at the base. The case was heated, and when the plug melted the generated steam escaped and impinging on the air drove forward the projectile. The absurdity of the idea is too obvious to need discussion. The Duke carefully examined it, and after asking many questions, remarked : " If this had been invented first and gunpowder afterwards, what a capital improvement gunpowder would have been."

The great war saw these " inventions " multiplied a thousand-fold. The spread of education, the availability of books from which at least a smattering of any subject could be obtained, and from the increase both in quality and quantity of newspaper news a consequent closer knowledge of what was happening—all these factors helped to add to the crop of ideas. In many cases undoubtedly these ideas were elaborated and worked out by the inventor, adopted by the authorities, and proved of the highest value. These cases were, however, greatly in the minority, and were generally the work of one who had at least some pre-knowledge of his subject. Such a man was the late Wing-Commander F. A. Brock, R.N.A.S., of whom it can be said without fear of contradiction no one man did more for military pyrotechny during the great war, and possibly in no other single subject during the war was one man so invaluable.

Born in 1884, educated at Dulwich, he entered the firm of C. T. Brock and Co. in 1901, where he remained until the outbreak of war. Endowed with a marked inventive ability and a phenomenal memory, and brought up as it were in an atmosphere of pyrotechny, he developed a knowledge of pyrotechnic chemistry which was extraordinary and appeared almost instinctive.

A naval correspondent, writing in " The Navy," speaks of him as follows : " From H_2O to WO_2 they knew all



WING-COMMANDER FRANK ARTHUR BROCK, R.N.A.S.
Killed at Zeebrugge, April 23rd, 1918.

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about it, or thought they did until the wayward genius of the Commander, who never pretended to be a chemist, taught them that there were permutations and combinations to the n th degree that they had never dared to think of.

“Wing-Commander Brock’s great secret was originality. To the accepted formula he would add just a touch of the unexpected. The chemists would say it can’t be done, or it wouldn’t work. Sometimes it did not, but often it did, very nearly. And Brock’s pioneer brain touched it a bit more—and lo ! the impossible and the unexpected had arrived.”

During his connection with the firm he had travelled over a large portion of the world on its behalf. His experience at a comparatively early age in organising and carrying out large displays—where the safety of thousands of spectators is in the hands of the directing mind—no doubt did much to develop those qualities of self-reliance and self-confidence which were so marked a characteristic of his Service career.

Wing-Commander Brock was responsible for many pyrotechnic inventions, and for the practical development of many ideas and inventions not his own, but which required technical knowledge and experience to ensure success.

It is perhaps as the “inventor of the smoke screen” that he is best known, a quite mistaken idea, the fallacy of which a moment’s consideration will show. There are many references to the use of smoke as a screen in classic times and even in mythology. The smoke ball, as we have seen, was a recognised military store up to the middle of the last century. It is just as absurd to credit Commander Brock, or for that matter any living man, with the invention of the use of the smoke screen in warfare as to credit the inventor of a patent fire extinguisher with the idea of putting out fires.

What Commander Brock did do was to provide the means when the demand arose of producing smoke suited to the

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particular purpose for which it was to be used, whether for screens, signalling, or other purposes.

As an example the " E " float may be cited. A demand had arisen for a smoke-producing device for use on board merchant ships to assist escape from enemy submarine attack. Commander Brock, with characteristic energy, in a very short space of time produced the " E " float, which for ease in manipulation by untrained operators and volume of smoke produced was probably unsurpassed by any subsequent device, and on the score of cheapness it undoubtedly held the field.

This store, which was in reality a triumph of pyrotechnic design, was in appearance so simple as to mislead some at least to whom greater insight might have been credited as to the ingenuity of its design. Counsel at a sitting of the Royal Commission on Awards to Inventors, described the float as " half-a-dozen or so drain rockets in a box." A remark which might be considered as accurate as to describe a clock as some pieces of metal in a box, were it not for the fact that the box in question contained no drain rockets, or anything resembling them more closely than one firework resembles another designed for quite a different purpose.

The requirements to be met were as follows : The apparatus was to be used by men whom by nature of their employment it was impossible to train individually, therefore its ignition must be simple and at the same time certain and quick in action, and carried on the float itself; a chamber had to be provided in which to as it were accumulate the smoke generated, which chamber had of necessity to have holes through which the smoke could issue. As the float had to be dropped after ignition from the deck of the vessel into the sea, and would consequently be submerged for a short time, these holes must be in some way sealed until the float rose to the



Smoke Float in Action.

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surface. The pyrotechnic compositions which produce the greatest volume of smoke were found to take some considerable time to attain their maximum of production, and separate units had to be included which would develop almost instantaneously a big mass of smoke, pending the generation of the main supply.

In addition, the float must be so constructed as to remain efficient when stored on the deck of a merchant vessel in all weathers and conditions.

Two hundred thousand of these floats were issued during the war.

The subject of smoke is one which naturally attracts the attention of the pyrotechnist, although in what might be called a negative direction.

For display work the elimination of smoke is obviously of greater importance than its production, but inquiry into the one of necessity leads to a knowledge of the other.

In some few cases the smoke generated is of value in adding to the effect of the burning composition ; the most noticeable case of this is the use of coloured fire as flares, that is to say, burnt in masses for the illumination of trees and other natural features. Some years ago Messrs. C. T. Brock & Co. spent considerable time in eliminating as far as possible the smoke from coloured fire, when it was found that without the smoke the result was very poor. It was the reflection of the colour on the smoke upon which the illumination depended for its effect. This, however, is hardly germane to our subject, but is mentioned to indicate how largely the question of smoke enters into the work of the modern pyrotechnist.

Commander Brock had, apart from his ordinary work, been engaged for some months prior to the outbreak of war on the question of the production of smoke for the Admiralty, and had also interested himself in the subject for commercial

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purposes, such as insecticide and other uses. He was therefore in a position, when the demand arose for smoke both for naval and military use, to start research in the matter considerably ahead of other inquirers, and to produce immediately a smoke that would supply the needs for the time being until more satisfactory means could be evolved.

The Royal Naval Experimental Station at Stratford, of which he was in command and which he organised and brought into being, had many activities besides smoke. But even the exacting work of controlling its many activities was not sufficient for the Commander's untiring energy; the few moments he could snatch from his duties and the many he stole from sleep were devoted to the invention and elaboration of war devices. His greatest achievement was the Brock anti-Zeppelin bullet, for which he and he alone is responsible, and which beyond any shadow of doubt delivered this country from the terror of the Zeppelin raids.

His other inventions include many purely pyrotechnic smoke devices and inventions connected with the production of smoke, such as igniters which were used to start the action of smoke production, the Dover flares of one million candle power each, used by the anti-submarine patrol in the Straits of Dover, and burned to the extent of several hundreds every night.

He was also responsible for several forms of stars for use in Very pistol cartridges.

Captain Carpenter, V.C., in his splendid book, "The Blocking of Zeebrugge," writes as follows of his work in connection with that operation :

" It would be difficult for anybody to speak too highly of Wing-Commander Frank A. Brock. He was a rare personality. An inventive genius, than whom the country had no better, it was his brain that differentiated this blocking enterprise

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from all previous attempts in history in one most important particular. The difficulty of reaching the destination in the face of a strenuous opposition had hitherto brought failure, but he provided an antidote in the form of a satisfactory artificial fog designed to protect the blockships from the enemy's guns during the critical period of approach. That in itself was a wonderful achievement, but his inventive mind was not satisfied therewith. To him we owed the special flares intended for turning darkness into light.

“ A special buoy was wanted—one that would automatically provide its own light on being thrown into the water. Brock made so little of the problem that he produced such a buoy, designed, constructed and ready for use in less than twenty-four hours. Special signal lights were required : Brock produced them. Flame projectors, far exceeding anything hitherto known, were mooted: Brock produced them also. No matter what our requirements were Brock was undefeated. With a highly scientific brain he possessed extraordinary knowledge of almost any subject. He had travelled much and could tell you all that was worth knowing of any country from Patagonia to Spitzbergen. He was no mean authority on old prints and books, was also a keen philatelist, and was blessed with a remarkable memory. Wherever he went he carried with him a pocket edition of the New Testament, which was his favourite possession ; his knowledge of the contents was quite unique. And with it all he was a great shot and an all-round sportsman. His fine physique was well remembered by many a Rugby footballer from the days when he played in the pack of one of the leading club fifteens. His geniality and humour were hard to beat. But of all his qualities, optimism perhaps held first place. At times we, who were far from being pessimistic, thought his optimism excessive, but it was justified absolutely with regard to the success of the enterprise.”

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The "Very" was a pre-war invention, patented in 1878; it was not adopted into the Service until about ten years later. It consists of a short-barrelled pistol of 1 inch calibre—or rather that was the original size, a $1\frac{1}{2}$ inch pattern was introduced during the war, and subsequently a $1\frac{1}{2}$ inch pattern with a longer barrel and shoulder piece.

The original cartridge was in effect a single star Roman candle, fired by percussion. A small propelling charge drove out a single coloured star, either red, white, green or blue. The star rose to a height of about 300 feet. These were used purely for signalling purposes.

The war suggested another use of the "Very" pistol, that is for illuminating purposes, and various illuminating stars were introduced, both to light up upon reaching their objective with a range of two to three hundred yards, and to hang suspended from a parachute, similar to the old parachute light ball, but with many times the brilliance, although considerably less in size.

The difficulty of identifying coloured stars in daylight suggested the use of coloured smokes. These were successfully evolved by Major Wicks and Captain Gray, an achievement of far greater difficulty than the casual observer might think.

Apart from these synthetically prepared colours, the yellow smoke natural to orpiment was much used in signal stars.

Later stars were suggested by Commander Brock, which ascended burning white and at their height broke into two, and in a subsequent pattern into three, stars of varying colours.

The rifle grenade, which was fired by a rod fixed to the base of the grenade and running down the barrel of a rifle, being blown out by a cartridge without a bullet, was also fitted up for signalling purposes. Upon opening, a series of lights, arranged to code, were suspended from a parachute.

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Recognition and illuminating lights were constructed for use from aeroplanes, and were ignited by dropping through a launching tube fixed to the machine, which made contact and fired them electrically as they passed through.

Landing lights and wing-tip lights, electrically ignited, were other stores used in connection with aerial warfare.

Another was the incendiary bomb. Until the outbreak of war the incendiary composition for use as stars in incendiary shells was of a most primitive nature, and even during the war incendiary compositions were used which were ridiculous in comparison with those produced later.

The construction also of some of the earlier efforts was quite as absurd. Projectiles were devised in a thin paper case, intended to be dropped from heights of many thousand feet, and ignite on impact, whereas the impact produced by the velocity of a projectile after such a fall was sufficient to scatter the case and its ingredients in all directions.

It was the use of aluminium in pyrotechny which pointed the way to real incendiary composition, composition which exceeds the temperature of these primitive pitch and other elementary compositions by many times more than the flame of a candle exceeds the temperature of ice.

Bombs containing thermit, and later on thermalloy (a composition which set hard, and did away with the necessity of a case), were terrible weapons, giving a temperature which has hardly been exceeded by other means.

These compositions were almost identical with some of those containing aluminium used in pyrotechny for a considerable time before the war, but of course not for incendiary purposes. The intense heat is naturally accompanied by brilliant light, which was of great value to the pyrotechnists, the more so as aluminium compositions do not deteriorate on being kept as do those containing magnesium, and although

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the light is not quite so brilliant, and has less actinic value, the fact that it is considerably cheaper, combined with its keeping qualities, renders it a very satisfactory substitute for that rather expensive metal, in very many cases at least.

CHAPTER XI

THE CIVIL USE OF FIREWORKS

THE utility of fireworks and the number of purposes to which they have been applied are far greater than most people imagine, both at sea, where possibly their usefulness is most fully exploited, on land, and since the war and its consequent developments of aeronautics, in the air.

Firework signals at sea are used in almost endless variety for the purpose of identifying vessels at night. Each shipping line has its own signal or signals, which are fired on such occasions as when passing Lloyd's signal stations. These signals consist of hand lights, Roman candles, rockets, or Coston lights. The last-mentioned is a small hand light which is arranged to burn with either one colour or two or more colours in succession. This signal is used by the majority of foreign vessels. The signal used may be either lights burnt singly or together, or a light or lights burnt in combination with Roman candles or rockets. By making use of the various combinations a great number and variety of signals have been arrived at : a few typical examples will illustrate the kind of signals used.

The Zud-Amerika Lyn of Amsterdam burns a white light at stern, green at bridge and blue at bow. The White Star have a green light at bow and green at stern. W. Johnston and Co., a green light followed by a Roman candle, throwing three red and three blue stars, followed by a white light. The Aberdeen have a red light followed by a Roman candle, throwing red, white and blue stars three times successively, shown from aft. J. L. Burnham and Co., a blue light changing to white, then to red, followed by a red star.

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The Cunard Line, off the coast of Ireland, fire a blue light followed by two golden star rockets. The Ulster Steamship Co. fire three vertical lights, yellow, blue and red, followed by two Roman candles fired together, each throwing two yellow, two blue and two red stars.

These examples will give some idea of the variety of signals used ; they are often followed by another signal, or rather have a suffix which if fired has a particular meaning. For instance, a red light after the signal may mean " All's well," or a green may signify a wish to communicate. Some lines bring the whistle into the signal and combine long and short blasts with pyrotechnic signals.

Besides the house signals there are some generally accepted signals used by all vessels. A blue light is the signal for a pilot in all waters, except those of the United States. It is curious, however, that no universal pyrotechnic signal of distress has yet been arranged, although in 1889 Mr. F. Crundall endeavoured to get a standard distress signal recognised by shipping throughout the world. This signal, which consisted of a Roman candle surrounded at the mouth by four lights which burnt simultaneously with it, was demonstrated before the Board of Trade, and was distinguishable across the Channel at Dover, but was, however, not universally adopted.

Another extensive field use of pyrotechnic signals at sea is in the fishing industry. Lights and rockets are used to communicate between vessels of the fishing fleets and with the carriers.

The use of such signals by the coastguard and the Life-boat Institution and at harbours and ports throughout the world is also very great.

Another pyrotechnic store of the greatest utility is the line-carrying rocket, a device which has been responsible for the saving of thousands of lives.

The credit for suggesting this use of the rocket appears

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to belong to a Mr. Trengouse, of Cornwall. This was in 1807. The proposal did not, however, make as much headway as it should have done, owing to the fact that Capt. Manley had that year introduced a device with a similar purpose, the line being carried by a shot fired from a mortar. This idea had been previously worked out by a Sergt. Bell of the Royal Artillery and by La Fère, a Frenchman, the two working independently.

The Manley apparatus was officially adopted, and stations established at forty-five positions round the coast.

The rocket method was, however, revived in 1826 by a Mr. Dennett, of Newport, Isle of Wight, and four stations were established on the island for the use of rockets of his pattern. The advantages of the rocket over the shot apparatus are obvious—the lightness and mobility of the rocket trough as compared with a mortar, the fact that the rocket traces its own flight, which can be seen and followed even at night, not to mention greater simplicity in working. However, it was not until 1855, when a rocket of greater range was invented by Col. Boxer, of the Royal Laboratory, that the rocket as a line carrier came into its own.

The Boxer rocket consisted actually of two rocket cases joined head to tail, and so arranged that when the first case had burnt out it was blown off, and the second gave renewed impetus. This rocket is still in use at the Board of Trade rocket stations.

A further development of the line-carrying rocket which is making rapid headway is a compact apparatus designed for use on the wrecked vessel to carry a line to the shore.

This system has two great advantages, namely, the target is so much greater when firing from the ship, consisting as it does of the whole coast line, whereas the ship forms in comparison an insignificant mark from the shore. Again, a vessel

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is generally wrecked on a lee shore, so that in firing from the ship the rocket travels with the wind.

Both the Brock and Schermuley systems are designed for this purpose, and there is little doubt that in a few years all vessels will carry their own means of establishing communication with the shore.

As a further development of the line-carrying rocket, it is interesting to note that Congreve, in association with Lieut. J. M. Colquhoun, took out a patent for the use of the rocket as a harpoon in whale fishing, which, if it proved satisfactory in use, must have been a marked advance, especially as this was before the advent of the now universally used harpoon gun.

Another pyrotechnic invention responsible for the saving of many lives is the Hale's Light apparatus. This apparatus is fitted to a lifebuoy, which is arranged for launching from a vessel's bridge; the act of launching ignites a flare, enabling the person in the water to see the buoy and the rescuing boat to pick them up.

The practical use to which fireworks have been put on land are many. Probably that which comes most readily to the mind is the sound signal or alarm. Many fire brigades whose members are volunteers and therefore scattered use aerial maroons to warn and call them for duty. These maroons became familiar to Londoners during the air raid period in the late war.

The maroon has also been adopted for firing with a trip line as a burglar alarm, or for protecting game preserves or similar purposes.

Another well-known pyrotechnic sound signal is the fog signal used on the railways, which consists of a tinned iron envelope containing a mixture of chlorate of potash and red phosphorus. It is secured in position on the rail by two lead



Crystal Palace. From a photograph taken by the light of a magnesium shell.
The crowd at "Brock's Benefit" (64,000 persons present).

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clips provided for the purpose, and is fired by percussion on the impact of the engine wheel. Bird scarers, consisting of a series of single crackers connected by a time fuse, and so arranged as to fire at regular intervals, have been much used for the protection of seed and crops.

The miner's squib and chieza stick or fuse lighter are to all intents port-fires for lighting the fuse in blasting operations in mines, their form and composition being adapted to the particular circumstances of their use.

The use of pyrotechnic compositions for photographic purposes is well known ; those in use at the present generally contain magnesium, which has greater actinic value than any other firework composition.

Magnesium lights fitted up to fire with a trip line have been successfully used for obtaining photographs of big game in their native surroundings at night.

Smoke pyrotechnically produced has for several years been used for the testing of drains, and recently successful experiments have been carried out establishing the value of smoke as a protection for fruit blossom against frost.

It has also been used as an insecticide for use against various kinds of parasites ; a poisonous smoke has been found of great use in the dislodging and exterminating of rats.

Another agricultural use of pyrotechnic, or in this case perhaps more correctly explosive composition, is the use of explosive cartridges for ploughing ; that is, cartridges are exploded at a certain depth in the ground, the effect being to break up the subsoil. The explosive used is a mild and cheap form of dynamite.

The use of rockets and other explosive fireworks for producing rain has been much discussed recently. Many writers deny the possibility of success by such means. There cannot be the slightest doubt, however, that given clouds in the right

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condition and altitude it is quite possible to cause rain. The writer has seen it done, not once but many times ; generally it must be admitted when the rain was not wanted. Maroons fired in wide-mouthed mortars have been used on the Continent for some years to break up hail clouds and bring them down in the form of rain over the vineyards, where a hail storm is a serious calamity to the wine grower.

The use of pyrotechnic signals in connection with aerial travel is gradually increasing. The stores used are practically those evolved and adopted during the great war, modified in some cases to suit peace time requirements, but substantially they are those described in the chapter on Military Pyrotechny.

LIST OF THE PRINCIPAL INGREDIENTS USED IN PYROTECHNY AT THE PRESENT TIME.

Force and Sparks Compositions.

Saltpetre	Aluminium and Alloys
Sulphur	Magnesium and Alloys
Charcoal	Lampblack
Mealed Gunpowder	Orpiment (Sulphide of Arsenic)
Iron Borings	Black Antimony (Sulphide of
Steel Filings	Antimony)
Zinc Filings	

Chlorate Colour Compositions.

Chlorate of Potash or Perchlorate of Potash.

Red	{	Nitrate of Strontia	Blue	{	Carbonate of Copper
		Carbonate „ „			Sulphide „ „
		Sulphate „ „			Arsenite „ „
Green	{	Nitrate of Baryta	Yellow—	{	Calomel
		Chlorate „ „			Oxalate of Soda
		Carbonate „ „			Carbonate „ „

For extra brightness Magnesium added.

Secondary tints obtained by mixtures of the above.

Non-Chlorate Colour Compositions.

Saltpetre	Orpiment
Sulphur	Aluminium
Charcoal	Magnesium
Black Antimony	Sulphate of Copper
White Arsenic	Borax

Burnables.

Shellac
Pitch
Sterine
Paraffin
Sugar of Milk
Linseed Oil

Agglutinants.

Shellac and Spirit
Starch Paste
Gum Water
Linseed Oil
Dextrine

Sound Producing.

Gunpowder
Guncotton
Picrate of Potash
Chlorate of Potash
Aluminium

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